BENEATH THE BOTTOM LINE: AGRICULTURAL APPROACHES TO REDUCE AGRICHEMICAL CONTAMINATION OF GROUNDWATER

Volume II--Contract Papers

Part B: Management Approaches

1. Pesticides and Nitrates in Ground Water: An Introductory Overview -- Stuart Z. Cohen

2. Mapping Groundwater Vulnerability to Agricultural Uses on a National Scale in a Geographic Information System -- Margaret Maizel, Kelly Chan

3. Agricultural Best Management Practices: Implications for Groundwater Protection -- Terry J. Logan

4. Farmstead Assessments: A Means to Manage Farm Sources of Groundwater Contamination of Groundwater -- Gary Jackson, Susan A. Jones, Bruce Webendorfer

These contractor documents were prepared for the Office of Technology Assessment (OTA) assessment entitled Beneath the Bottom Line: Agricultural Approaches to Reduce Agrichemical Contamination of Groundwater, OTA-F-418 (Washington DC: U.S. Government Printing Office, November 1990). They are being made available because they contain useful information beyond that used in the OTA report. However, they are not endorsed by OTA, nor have they been reviewed by the Technology Assessment Board. References to them should cite the contractor, not OTA, as the author. Suggested reference style is shown on the title page of each contractor document.

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PESTICIDES AND NITRATE IN GROUND WATER: AN INTRODUCTORY OVERVIEW

by

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August 1989

This contractor document was prepared for the Office of Technology Assessment (OTA) assessment entitled Beneath the Bottom Line: Agricultural Approaches to Reduce Agrichemical Contamination of Groundwater. It is being made available because they contain useful information beyond that used in the OTA report. However, they are not endorsed by OTA, nor have they been reviewed by the Technology Assessment Board. References to them should cite the contractor, not OTA, as the author; a suggested citation format follows:

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Pesticides and Nitrates in Ground Water: An Introductory Overview for the Office of Technology Assessment's Report to Congress

Abstract

The assessment of agrichemicals in ground water in the United States became a prime focus of many in the late 1970's. At that time, normal agricultural practices became linked to elevated nitrate levels in ground water. Also, DBCP became the first pesticide banned due to ground water contamination.

Since that time, an extensive amount of monitoring data have been accumulated, but the true extent of the problem is not known. Confounding factors in study design prevent one from knowing whether the findings understate or overstate the problem. In recent studies, 46 pesticides have been reported in ground water from 26 states as a result of field use; these findings represent at least 11,000 detections out of 45,000 wells. Nitrate concentrations exceed the Maximum Contaminant Level in 8,200 wells out of 124,000 wells sampled in a USGS study.

Other countries are also grappling with the problem. The European Economic Community is struggling to implement some rather stringent limitations on allowable levels of pesticides in drinking water.

Some attention is also being focused on special cropping systems, including conservation tillage and use of pesticides and fertilizers on turf. Preliminary observations from a limited data base indicate that pesticide and nitrate leaching through turf is minimal relative to row crop agriculture. Data on the relationship of conservation tillage systems and ground water contamination are inconclusive.

Institutional and budgetary constraints exist to reduce contamination by pesticides and nitrates in ground water. The point source contamination problem is most easily addressed and resolved. Resolution of the nonpoint

source problem is likely to be more hampered by fundamental institutional and budgetary constraints. However, many of the problems in this area could be resolved if new EPA, USDA, and USGS initiatives achieve their ambitious goals.

A series of recommendations are offered in this report to help solve the problems.

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Foreword

The state of knowledge, the degree of interest, and the degree of frustration in the area of agrichemicals in ground water have all increased exponentially within the last decade. Studies that have focused on vulnerable regions and individual chemicals or small groups of chemicals have found at least 5,500 wells with pesticide concentrations exceeding some health advisory level and at least 8,200 wells with nitrate concentrations exceeding the Maximum Contaminant Level. Yet the true extent of the problem is not known. For example, many of the detections represent products that are no longer in significant use in the United States. We do not know whether this nonrepresentative subsampling of the nation's 13 million wells overstates the severity of the problem or whether it represents the tip of the iceberg.

Meanwhile, there has been no uniform approach to dealing with the problem across the country in terms of legislation, regulation, policy, education, and remediation. Thus several committees in the House and the Senate have asked OTA to write a comprehensive assessment discussing approaches to reducing the problem.

This paper was commissioned by OTA to help them write their report to Congress.

I. The State of Knowledge

Pesticides are emphasized in this and all sections of this report relative to fertilizers. Although some information on the latter are provided, the reader is urged to consult the following excellent reviews of the subject:

1. Proceedings of the Agricultural Impacts on Ground Water--A Conference, Omaha, Nebraska, August 11-13, 1986; National Water Well Assoc.; Dublin, Ohio, 1986.

2. Proceedings of the Agricultural Impacts on Ground Water--A Conference, Des Moines, Iowa, March 21-23, 1988; National Water Well Assoc., Dublin, Ohio, 1988.

3. National Water Summary 1984--Hydrologic Events: Selected Water-Quality Trends and Ground Water Resources, U.S. Geological Survey Water Supply Paper 2275, Washington, D.C.: U.S. Government Printing Office, 1985.

4. National Water Summary 1986--Hydrologic Events and Ground Water Quality, U.S. Geological Survey Water Supply Paper 2325, Washington, D.C.: U.S. Government Printing Office, 1988.

A. The Extent of Occurrence of Agrichemicals in Ground Water

The scientific community began to emphasize the study of nitrates in ground water in the mid 1970's (Olson et al., 1973; Hallberg, 1986) and the study of pesticides in ground water in the late 1970's (Spalding et al., 1979 and 1980; Cohen et al., 1984). Since that time, at least 100 studies each of pesticides and nitrates in ground water have been conducted (EPA, 1988, and Hallberg, 1986, respectively).

Good research raises as many questions as it answers. By this criterion alone, much good research has been done in this field. Many questions have been answered and many more have been raised in the areas of pesticide mobility and persistence, agronomic practice, and hydrogeology. In almost all areas discussed in this paper, further research is warranted.

The plain fact is that the true extent of occurrence of agrichemicals in ground water is not known. What we do know is that reports of pesticide and nutrient contamination of ground water are increasing. The remainder of this section will attempt to summarize the state of knowledge, limitations in the data, and current activities.

1. The increase in U.S. pesticide data. Ten years ago, there were occasional reports of pesticides in ground water as a result of agricultural practice. For example, Spalding et al. (1979 and 1980) reported herbicides and nitrates in Nebraska

wells. By 1984, EPA staff were able to document findings of 12 pesticides in ground water from 18 States as a result of normal use (Cohen et al., 1984). Cohen et al. updated the count to 17 pesticides in 23 States in 1986. But by this time the authors had to state "At least 17 pesticides have been found ..." (emphasis added) due to the tremendous increase in the number of studies in this area such that the authors could not be sure they had captured it all. (The summarized results were based on approximately 11,500 detections from approximately 45,000 wells, out of approximately 13,000,000 wells nationwide (Cohen, 1988).) In a 1988 update, the numbers of pesticides and States increased significantly. However, this may represent an increased focus on the area of research, as opposed to representing a significant increase in occurrence.

EPA recently issued a preliminary report that summarized a massive data collection and evaluation exercise (EPA, 1988). Approximately 130 reports representing approximately 150 different monitoring studies for pesticides in ground water were evaluated two ways: an attempt was made to determine the quality of the data, and point sources and nonpoint sources were roughly distinguished based on each study author's comments. The key summary table is reproduced below.

Category	Description	No. of Pesticides Detected	No. of States with Detected Pesticides
1	All data	77	39
2	All data except suspected point sources or known poor quality.	74	38

Category	Description	No. of Pesticides Detected	No. of States with Detected Pesticides
3	Suspected field use data excluding known poor quality.	65	36
4	Confirmed, quality data of unknown or suspected field use origin.	52	27
5	Confirmed, quality data of known or suspected field use origin.	46	26
6	Confirmed, quality data of known or suspected point source origin.	32	12

Thus, 46 pesticides have been reported in the ground water of 26 States in association with "field use."

Two significant observations can be made about this summary: 1) both numbers in the important category 5 have increased significantly over the two previous summaries noted above, and 2) a national counting of incidents in the equally important category 6 has now been published for the first time. A distinction between categories 5 (nonpoint source) and 6 (point source) is important because the two contamination sources can be controlled by different mechanisms. This point is discussed in section I(D) of this report.

A map adapted from the EPA report, representing only category 5 results, is presented as Figure 1.

Figure 1. Confirmed Detections of Pesticides in Ground Water Resulting from Field Use

(Adapted from EPA, 1988)

Numbers of Pesticides Found in Ground Water As a Result of Agricultural Practice

"Only confirmed data attributed to agricultural uses."

(EPA, 1988)

B-15

Most of the detections in category 5 were herbicides and nematicides, although some insecticides and fungicides were also found. The complete list of confirmed detections is reproduced from the EPA report as Table 1.

The reader should be aware that EPA's data collection and evaluation task was enormous, and the results represented by Figure 1 and Table 1 should not be regarded as infallible. For example, it is this author's personal experience that the numbers on the map and the table could probably be increased in two States--Hawaii and Washington--and for at least two chemicals--EDB and DBCP. On the other hand, reports of detections can be misleading. One of EPA's category 5 detections was recently repudiated in public testimony by the State that produced the data (Corte-Real, 1989). In addition, it is difficult to believe that trifluralin, a pesticide with low mobility, would be reported as a nonpoint source detection in four States. Point sources are more likely for low-mobility pesticides. To its credit, EPA does intend to continually evaluate and periodically update this data base.

Pesticides that are mobile and persistent and are used in hydrogeologically sensitive areas in sufficient quantities have a high probability of leaching to ground water (Cohen et al., 1984). A mobile pesticide tends to move in the water phase without tightly adhering to soil. A persistent pesticide tends to degrade very slowly in the soil/water

Table 1. Confirmed Detections of Pesticides in Ground Water

(Copied from EPA, 1988)

(NOTE: Changes or corrections to the Health Advisory Levels immediately follow the table.)

TABLE 1-1
Confirmed Detections of Pesticides in Ground Water

Chemical Name	Cancelled or Severely Restricted	Analyte in NPS **	Health Advisory Level *** (ppb)	Normal Use			Point Source
				States with Detects	Maximum Concen. (ppb)	Median Concen.**** (ppb)	States with Detects
1,2-D	Y	Y	0.0013 *	4	550.00	4.50	
1,3-D		Y	0.20 *	1	270.00	123.00	1
2,4,5-T	Y	Y	21				1
2,4-D		Y	70	2	49.50	1.40	1
2,4-DB		Y					1
Alachlor		Y	1.5 *	12	113.00	0.90	7
Aldicarb		Y	10	7	315.00	9.00	
Aldrin		Y		2	0.10	0.10	
Arsenic	Y			1	N/A	N/A	1
Atraton		Y		1	0.10	0.10	
Atrazine		Y	3.0	13	40.00	0.50	7
BHC	Y	Y		1	4.30	2.70	1
Bromacil		Y	80	2	22.00	9.00	1
Carbofuran		Y	36	3	176.00	5.30	
Chlordane	Y	Y	0.03 *	1	1.80	1.70	1
Chlorothalonil		Y	1.5 *	2	12.60	0.02	1
Cyanazine		Y	9.0	6	7.00	0.40	1
DBCP	Y	Y	0.02 *	2	0.02	0.01	
DDT	Y	Y		3	402.00	1.70	1
Dacthal		Y	3500	1	1039.00	109.00	
Diazinon		Y	0.63	1	478.00	162.00	1
Dicamba		Y	7.0	2	1.10	0.60	1
Dieldrin	Y	Y	0.00219 *	2	0.02	0.02	1
Dinoseb	Y	Y	7.0	3	36.70	0.70	
Diuron		Y	14	1	N/A	N/A	
EDB	Y	Y	0.0005 *	6	14.00	0.90	1
Endosulfan		Y		1	0.40	0.30	1
Endrin	Y	Y	0.032				1
Ethoprop		Y		1	12.60	N/A	
Fonofos			14	2	0.90	0.10	
Heptachlor	Y	Y	0.076 *				1
Hexazinone		Y	210	1	9.00	8.00	
Lindane	Y	Y	0.026 *	3	47.00	0.10	1
Linuron		Y		1	2.70	1.90	
Malathion				1	53.00	41.50	1
Methamidophos				1	10.50	4.80	
Methomyl		Y	175	1	9.00	N/A	
Methyl parathion		Y	2.0	1	256.00	88.40	1
Metolachlor		Y	10	5	32.30	0.40	5
Metribuzin		Y	175	4	6.80	0.60	1
Oxamyl		Y	175	3	395.00	4.30	

TABLE 1-1
Confirmed Detections of Pesticides in Ground Water
(continued)

Chemical Name	Cancelled or Severely Restricted	Analyte in NPS **	Health Advisory Level *** (ppb)	Normal Use			Point Source
				States with Detects	Maximum Concen. (ppb)	Median Concen.**** (ppb)	States with Detects
PCNB							1
PCP		Y	220				1
Parathion				1	0.04	0.03	
Picloram		Y	490	3	49.00	1.40	1
Prometon		Y	100	1	29.60	16.60	
Propazine		Y	14	2	0.20	0.20	1
Silvex	Y	Y	52				1
Simazine		Y	35	7	9.10	0.30	
Sulprofos				1	1.40	1.40	
TDE	Y	Y	0.031	1	6.20	4.80	
Toxaphene	Y			1	4910.00	3205.00	
Triallate							1
Trifluralin		Y	2.0	4	2.20	0.40	1

* Lifetime exposure levels based on a 10-6 risk of causing cancer.

** National Pesticide Survey

*** Proposed Lifetime Health Advisory Level

**** Median of the concentration of positive detections for all confirmed studies. If a particular chemical does not list multiple studies, then the single study average is given. If the data base reports a single positive well, then the average concentration reported for that well is given.

Table 1(a). Changes or Corrections to the Health Advisory Levels Reproduced in Table 1.

(The updated numbers presented in this table were taken from "Health Advisory Summaries," January 1989, available from the Director, National Pesticide Survey, Office of Drinking Water (WH-550A), U.S. EPA, 401 M Street SW., Washington, D.C. 20460; and a summary table titled "Drinking Water Regulations and Health Advisories," draft dated 4/5/89, published by the EPA Office of Drinking Water.)

Pesticide	HAL in Table 1*	New HAL*
alachlor	1.5	0.4
carbofuran	36	40
DBCP	0.02	0.03
dicamba	9	200
EDB	0.0005	0.0004
heptachlor	0.076	0.008
lindane	0.026	0.2

* units = ppb

matrix. For example, a pesticide would be considered mobile and persistent if its soil/water partition coefficient, in a soil with 1% organic carbon, equals 1 and the degradation half life equals 100 days (after Gustafson, 1989 and Cohen, 1984).

Note that some States contain no detections. Does this mean that no pesticides might be found in their ground water? Does this mean that States with higher numbers have more pesticides in their ground water? The answer to both questions is 'probably no.' In some cases, States report relatively high numbers of different pesticides in ground water due principally to aggressive monitoring programs. Some reports of detections may also be due to false positives--acceptable chemistry combined with a failure to confirm--or actual laboratory errors.

Do the increases in pesticides detected and States with detections since 1984 represent an increase in the true extent of occurrence? The answer is that nobody knows. It is the author's opinion that the data represent mostly an increase in the number of monitoring studies, although preliminary data from Iowa researchers (Hallberg 1986) reported increases in agrichemical detections over time in northeastern Iowa. More recent data indicate that atrazine concentrations may be declining and nitrate concentrations may be relatively constant (Hallberg et al., 1988). However, a drought has eliminated aquifer recharge since March 1986, possibly explaining the new data (Libra, 1989).

Do all of these reports, summaries, and review articles tell us what is the true extent of occurrence of pesticides in ground water? The answer is 'no,' due to the limitations in the data. This point is addressed specifically below.

EPA is conducting an $11 million, statistically based, national survey of drinking water wells, which should characterize the national extent of the problem. Approximately 1,500 public and private wells are being tested. The survey's primary goal is to quantify the distribution of nitrate and summed pesticide residues in wells. Its secondary goal is to correlate the results with hydrogeologic and agronomic factors. If these correlations are successful, appropriate regulations and label restrictions could be designed at the national and State levels. The final report will probably be published in early 1991.

The Monsanto Company is also conducting a statistically based, nationwide survey for nitrates and five herbicides in 1,500 private, rural, drinking water wells (Holden et al., 1988). The final report will probably be published in early 1990.

2. Nitrates. Nitrate has been called "the most common contaminant identified in ground water" (Freeze and Cherry, 1979), and it probably is. For example, in 1984, 24,000 of 124,000 wells sampled nationwide were found to contain nitrate-nitrogen at concentrations exceeding 3 mg/L (USGS, 1985).

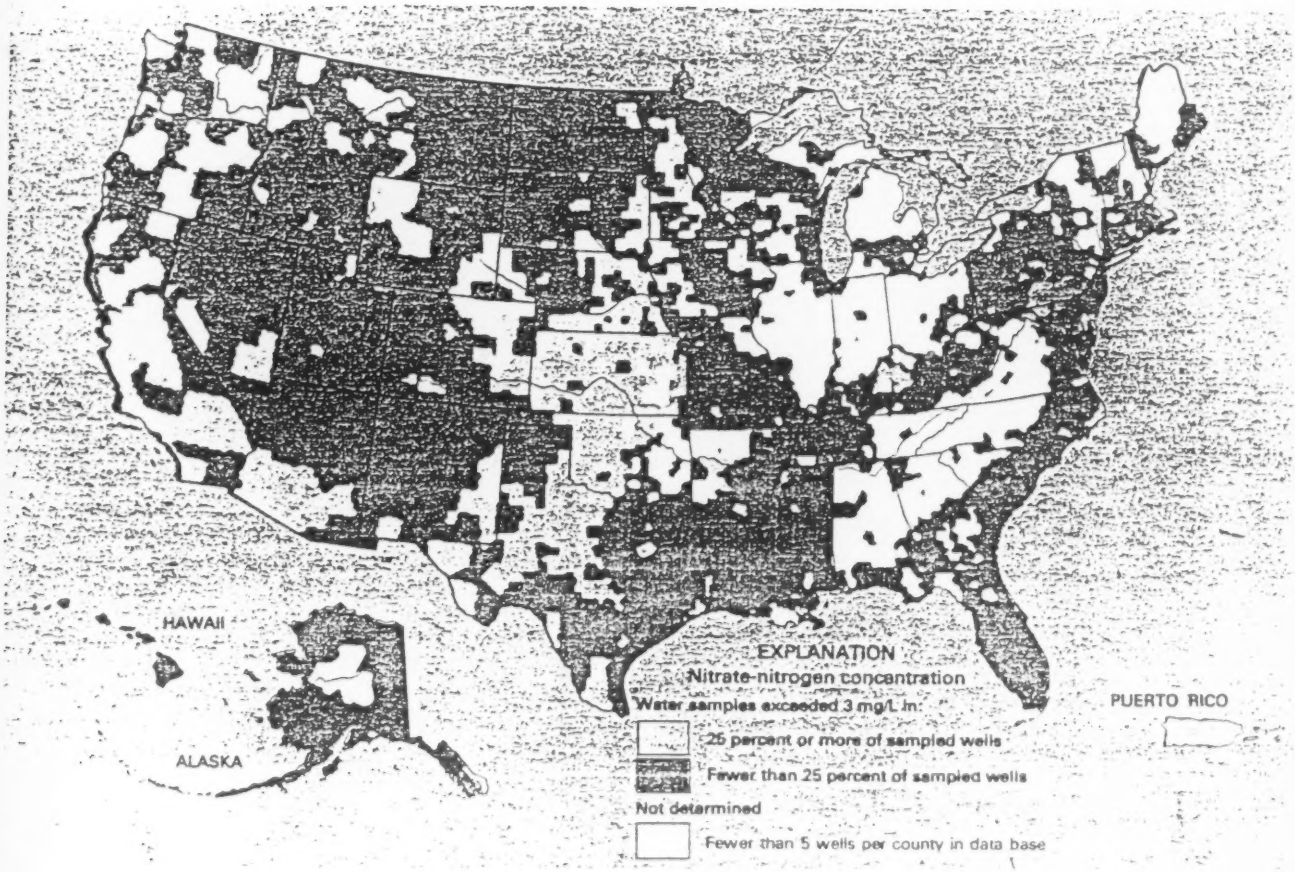
(Concentrations exceeding 3 mg/L "may indicate elevated concentrations resulting from human activities." This guidance by USGS acknowledges the fact that nitrates frequently occur naturally at low concentrations in ground water.) In that review, wells were found in all States except Hawaii and Alabama that exceeded the 10 mg/L MCL for nitrate-N. (Note that few data points were obtained from Alabama.) This information is depicted in Figure 2. Nitrate-nitrogen concentrations exceeded the 10 mg/L MCL in 8,200 (6%) of the wells.

In some areas, nitrate concentrations have been increasing (p. 107 of USGS, 1988; Hallberg, 1986). This may be due to significant increases in fertilizer use (Miller, 1980) and/or increasing occurrences of overapplication of fertilizers relative to crop uptake capabilities. This issue will be addressed more thoroughly by a different OTA contributor.

In areas of Nebraska, at least, occurrence of high nitrate concentrations has been shown to be correlated with triazine-herbicide concentrations (Spalding et al., 1980; USGS, 1988). Likewise, LeMasters and Doyle (1989) found a significant association between wells in Wisconsin containing greater than 10 ppm nitrate-N and detectable levels of pesticides. However, the same researchers did not find a quantitative relationship between pesticide concentrations and nitrate concentrations. Similarly, the correlation was very weak in one two-county area of Iowa (Libra et al., 1984). Thus nitrate "... may be an inexpensive test to use in identifying

Figure 2. Nitrate-Nitrogen Distribution in Ground Water of the United States and Puerto Rico.

(Copied from p. 97 of USGS (1985).)



(original artwork being reproduced by OTA)

potential areas contaminated by herbicides if herbicides are known to be used in the area under study" (USGS, 1988, p. 70), but more extensive data are needed for a broader correlation analysis. It may also prove to be a useful design variable in ground water study designs for areas where there are good nitrate data.

3. International activities. The European Economic Community (EEC) passed directives in 1979 and 1980 pertaining to prosection of ground water and drinking water. First, a Council Directive was passed that banned and restricted discharge into ground water of several substances and classes of compounds (EEC, 1979). The definitions of the substances/classes are broad--e.g., organophosphorus compounds, cyanides, mineral oils, and hydrocarbons--and exceptions are allowed based on toxicity, persistence, and bioaccumulation. Then another Directive was passed (1980) that established the following:

- A nitrates Guide Level of 25 mg/L (5.6 mg/L as N);
- A nitrates Maximum Admissible Concentration (MAC) of 50 mg/L (11.3 mg/L as N);
- An MAC of 0.1 µg/L for any individual pesticide and related products; and

- An MAC of 0.5 µg/L for total pesticides and related products.

Concurrently, drinking water monitoring requirements were also established for these parameters.

The pesticide requirements are, to say the least, controversial. These are technology-based standards: i.e., they are based on detection limits. Apparently, no risk assessments were done to support the MAC values. These numbers could easily be exceeded in many areas of the U.S., where specific toxicological properties of individual pesticides are considered when setting standards or advisory levels.

Uniform MACs may have been instituted to eliminate potentially unfair trade advantages. However, these specific numbers may have been created with little thought, or they may have been born out of the frustration of not having suitable alternative regulatory control over pesticide use in certain areas of Europe. One official of the Federal Republic of Germany's (FRG) health agency (BGA) told this author in 1985 that, without this regulatory tool, the existing regulatory mechanisms are relatively ineffective against pesticides that may reach ground water or surface water.

The controversy over the implementation of these MACs has not subsided. Some countries, such as Denmark and The Netherlands, have completely implemented the Directive.

Others, such as the FRG, are phasing it in slowly. For a while, Italy closed down several water supplies and banned atrazine, molinate, and bentazon in certain areas (Roberts, 1988).

Interest around the world has been increasing in this area. Researchers in Canada have been studying this problem at least since 1979, with a focus on point sources of contamination (Frank et al., 1987). A group of chemists organized by the International Union of Pure & Applied Chemistry (IUPAC) recently published an international assessment of the issue (Aharonson et al., 1987). Chinese and American abstracts on the subject were recently published for an IUPAC/China Pesticide Chemistry Workshop (1988). Studies of EDB in ground water have been conducted in four countries--the United States, Israel, Japan, and Australia (Pignatello and Cohen, in press).

4. Limitations of the data. In spite of these monitoring studies, we still do not know the true extent of the problem, particularly for pesticides. Four key factors are discussed below.

- Most studies lack a statistical basis. It is not valid to arbitrarily sample a few wells in an area and extrapolate the results to the whole area. Instead, sampling schemes with probability components must be implemented (Cochran, 1967; Cohen et al., 1986).

- Most studies oversample, in a nonstatistical manner, areas with relatively high ground water vulnerability and pesticide usage. Although this is a wise strategy for focusing limited resources, it tends to significantly overstate the extent of a problem over a broad area.

- Most studies focus on one pesticide or small groups of pesticides. This would tend to understate the extent of a problem relative to studies that use multiresidue methods and other techniques to detect multiple pesticides.

- The analytical chemistry sometimes has not been trustworthy. While preliminary screening methods have generally been adequate, confirmatory techniques sometimes have been inadequate or nonexistent.

EPA's national pesticide survey of drinking water wells will avoid these pitfalls.

B. Health Implications of the Concentrations Found

This issue may be explored three ways.

1. How often do the ground water residues exceed a Health Advisory Level (HAL)?

Between 1979 and 1986, approximately 5,500 of the approximately 11,000 detections of pesticides in ground water exceeded HALs (Cohen, 1988). However, most of the monitoring data obtained during this period focused on the pesticides with three of the lowest HALs--EDB, DBCP, and aldicarb. Thus the results were skewed toward finding pesticide concentrations that exceed HALs. When EPA reports the results of its national survey in 1989 or 1990, the fraction of pesticide results that exceed HALs in Table 1 is likely to be significantly lower.

Results summarized in Section I (A) above show that 6% of the sampled wells contained nitrates at concentrations exceeding the 10 ppm MCL.

2. What do the epidemiology studies show?

There are a limited number of epidemiology studies in this area. However, their results, at best, point out possible relationships that require further study and, at worst, raise concern about cancer mortality among people who work with certain classes of pesticides. Following is a brief review of some of the key studies in this area.

Jackson et al. (1982) found increasing risk between consumption of water contaminated with DBCP and male stomach cancer, total stomach cancer, and total lymphoid leukemia. However, other confounding factors prevented the researchers

from implicating DBCP as the cause of cancer. Burmeister et al. (1983) studied cancer mortality in Iowa and found elevated mortality ratios due to multiple myeloma (MM) and non-Hodgkin's lymphoma (NHL) associated with various agricultural activities, including pesticide use. Cantor and Blair (1984) observed elevated risk of MM for farmers residing in Wisconsin counties high in chicken inventory, fertilizer use, and acres treated with insecticides. In a review, Blair et al. (1985) noted that farmers frequently showed excesses of MM, NHL, leukemia, and several other cancers. Hoar et al. (1986) reported farm herbicide use, specifically 2,4-D, to be associated with excess incidence of NHL. However, EPA did not completely agree with the conclusions of this study at the time it was released and has not yet decided whether to classify 2,4-D as an oncogen. (A correction was subsequently issued (JAMA 256(24), 3351, December 26, 1986) which backed off the specific tie between NHL and 2,4-D use.) Finally, Alavanja et al. (1987) found that workers in the grain milling industry experienced elevated lymphatic and MM cancer mortality. The researchers postulated that this mortality excess was due, at least in part, to pesticide exposure.

Clearly these correlations, while not establishing a cause/effect relationship, point out the need for more definitive assessments.

3. How complete is the EPA toxicology data base?

EPA is frequently criticized for not having a complete toxicology data base on the 600+ active ingredients it regulates. Statements that only a handful of pesticides have been "fully tested" are technically true but misleading. There are approximately three to four dozen studies and tests required under 40 CFR Part 158 for the typical agricultural pesticide. These requirements were phased in during the 1978-82 time period. Data gaps exist for most chemicals, but a valid question is 'what constitutes a data gap?'

Data gaps can range from minor technical deficiencies to studies performed with unacceptable protocols to total lack of data. Many have been critical of EPA's 'checklist approach,' which has often manifested itself--particularly in the environmental fate area. Studies have been required that have no meaning, such as a photolysis study of a chemical that doesn't absorb light, simply because the studies are listed in 40 CFR Part 158. Studies have been rejected due to insignificant deviations from the so-called nonenforceable "guidelines." On the other hand, many have been critical of industry's and EPA's abuse in the past of the conditional registration process, whereby pesticide registrations have been granted prematurely pending the conduct of truly vital studies. There are signs, however, that both types of abuses of the data gap assessment process are being rectified and eliminated.

There are no good statistics describing the number of toxicology data gaps that are significant. The toxicology data base is probably more complete than the other data bases--ecological effects, residue and product chemistry, and environmental fate and exposure--due to the extensive "data call-ins" conducted in the early 1980's (Frane, 1989). In this program, registrants of all 400 food-use chemicals, which consist of most agricultural chemicals, were required to submit or resubmit valid data on the CORT requirements--chronic toxicity, oncogenicity, reproductive effects, and teratology. A similar, more limited environmental fate data call-in program was instituted for approximately 100 pesticides that had some mobility potential in 1984.

As a result of this massive data call-in effort, toxicology "data gaps" are estimated in most cases to be deficient studies, rather than missing studies (Frane, 1989). Unfortunately, the numbers are not available to determine whether "most" in this context means 55%, 95%, or some point in between.

There is one toxicology endpoint that deserves special mention. Pesticide immunotoxicity is a relatively new, rapidly evolving area that has been overlooked until recent years. Recently, EPA revised its biorational testing guidelines--Subpart M--to address immunotoxicity concerns, and plans to make some changes to the conventional pesticide toxicity testing guidelines in the near future (Sjoblad, 1988).

C. Nonpoint Sources vs. Point Sources

For purposes of this discussion, "nonpoint source" will be defined as the land application of agricultural or turf pesticides and fertilizers in the manner in which they were intended to be used. "Point source" in this context means a spill, application, or disposal activity that is localized and results either in a direct introduction of a chemical to a well or in an overapplication to land.

The distinction between these two contamination sources is important because they can be controlled by completely different regulatory and education mechanisms. Nonpoint sources of pesticides can only be controlled centrally, through competent and responsible registration decisions by EPA, State regulatory agencies, and pesticide registrants. Point sources of pesticides are best controlled through good product stewardship by the users, informative product label statements, educational programs, and, sometimes, formulation changes by pesticide registrants.

Point sources of pesticide ground water contaminants have not received much attention in the literature, but in some areas they may be more of a problem than nonpoint sources (Graham, 1988). Point sources may also introduce different pesticides to the subsurface than nonpoint sources. This is because point sources often 'short-circuit' the typical leaching process, which consists of slow capillary movement of soil pore water that is in constant contact with soil material. Instead, point sources may be direct-

ly introduced to ground water through a wellhead via improper chemigation techniques or they may migrate through the soil in an organic phase consisting of bulk liquid pesticides or solvents following spillage or improper disposal. The implication of this short-circuiting process for point sources is that any pesticide could contaminate ground water through this route, not just those pesticides that are mobile and persistent (Cohen et al., 1984).

Following is a review of some representative assessments that have distinguished between point sources and nonpoint sources of contamination.

The 1988 EPA report represents the first national accounting of pesticides found in ground water as a result of point sources. Category 6 of the EPA report identifies 32 pesticides found in the ground water of 12 States as a result of known or suspected point source origin. Many of these pesticides are relatively immobile chemicals--i.e., tightly bound to soil--that are not likely to leach to ground water following normal application. It is likely that the number of States in this category will increase significantly in the future. The number of pesticides might also increase.

Hallberg (1986) identified potentially serious point source contamination problems caused by many of Iowa's approximately 1,500 farm-chemical supply dealerships. He noted pesticide concentrations in soils that exceeded 200,000 ppb and concentrations in nearby ground water that exceeded 500 ppb, two orders

of magnitude greater than normal background levels for the area. The nitrate-N concentration was as high as 117 ppm in one location, and was 20 ppm or greater in all ground water samples from the 10 farm-chemical supply dealerships that were studied in Iowa.

The Illinois Environmental Protection Agency (IEPA) and the Illinois Department of Public Health (IDPH) recently completed three studies with results indicating significant point source contamination. No pesticides were detected in samples from 343 public water supply wells that were selected, in part, by their hydrogeologic representativeness and the availability of well logs (Clark and Sinott, 1988). Three wells where sub-ppb concentrations of herbicides were found were located within 50 to 700 feet of agricultural chemical operations. A much higher level of contamination was found in a study that focused exclusively on agricultural dealerships (Long, 1988). There are approximately 1,500 agricultural mixing and loading facilities in Illinois. Approximately 80 of the sites were sampled and results from approximately 50 of the sites were summarized in this IDPH report by Long. Over 75% of the well samples had residues of at least one pesticide. Corn and soybean herbicides were detected in the highest number. Most results were in the low-ppb range, but several pesticide concentrations exceeded 1,000 ppb. Water from 64% of the wells exceeded the 10 ppm MCL for nitrate-N, and the median and mean concentrations were 25 ppm and 108 ppm, respectively.

Finally, Canadian researchers have also been studying the impact of mishandling pesticides on ground water quality. For example, Frank et al. (1987) investigated spill events involving 104 rural wells and found pesticides in 79 of the wells due to: 1) spills of pesticide concentrates; 2) back siphoning of pesticide solutions; and/or 3) spills from contaminated rinsates. In addition, they reported 55 wells with pesticide residues resulting from spray drift and/or surface runoff.

Clearly, mishandled agrichemicals can serve as a point source of introduction to ground water, resulting in pesticide and nitrate concentrations spanning the ppb range and the low ppm to high ppm range, respectively. Recognizing this fact, EPA and the States of Florida and Nebraska have instituted chemigation controls to prevent back-siphoning of pesticide solutions into wells. Many other States have probably implemented similar measures.

It is this author's experience that pesticide residues exceeding the 500 ppb-1,000 ppb range in ground water are caused by point source contamination. However, the converse is not true: low concentrations may derive from point or nonpoint sources.

D. Limited Data Base of Special Cropping Systems: Turf and Conservation Tillage

1. Turf

OTA includes turf in its definition of agricultural lands. In addition, citizen activists have been focusing on pesticide use on golf courses. Thus the following discussion is pertinent.

The data available on agrichemicals leaching through turf are very limited. But there are indications that, other factors being equal, agrichemical leaching potential through turf is significantly less than through agricultural environments, such as row crops. This is likely due to a combination of characteristics of turf:

- The high fraction of crop intercept (ground cover).
- The thatch layer.
- The dense, bioactive root system.

According to Prof. Richard Cooper, Dept. of Plant & Soil Science, U. Mass. at Amherst, Kentucky Bluegrass and Bentgrass typically have 1,500-2,000 plants/ft^2 and 1-2 lbs. of roots/ft^3.

A study of the impact of turf pesticides on ground water was recently completed on Cape Cod, Massachusetts (EPA, 1986). Sixteen monitoring wells were installed on four golf courses with vulnerable hydrogeology. Water and soil were sampled and analyzed for 18 pesticides and metabolites. No currently-registered pesticides were detected at concentrations approaching health advisory levels. Nine of the chemicals were not detected in 1½ years of monitoring.

Similar conclusions have been reached based on evaluations of a few other field, lysimeter, and modeling assessments of pesticide and nitrate movement through turf (Gold et al., 1988; Morton et al., 1988, Cohen, 1989). Thus a limited data base indicates that pesticides applied to turf generally do not appear to threaten ground water quality unless the pesticides are mobile, persistent, and toxic.

2. Conservation tillage

Mathematical modeling (Donigian and Carsel, 1987) indicates that conservation tillage (CT) practices should increase the flux of agrichemicals to ground water. This is due to the facts that CT tends to retain more moisture in the soil, and, according to the authors, it generally requires more herbicides to be applied. However, there are other reports that dispute these conclusions.

Baker et al. anticipate that pesticide use in the Corn Belt should not increase significantly with increased conservation tillage use.

Preliminary field data about leachate are inconclusive. Neither Helling (1986), Logan et al. (1980), Randall et al. (1988), nor Bicki and Felsot (1988) noted an impact by CT practices on agrichemical leachate flux. But Bourke et al. (1988) noted a 2-8 fold increase in atrazine and simazine leaching in no-till plots on silty clay loams in Pennsylvania.

More studies are needed on this topic.

II. Regulatory Authorities and Reactions to Pesticide Contamination Incidents

Federal, State, and county agencies and pesticide companies have reacted differently in different contamination incidents. In this section, an attempt is made to describe briefly the regulatory framework in this area. Important and illustrative actions are also described.

A. The Multi-Level, Multi-Agency Structure of Approaches to Protecting Ground Water

At the Federal level, the EPA regulates use of pesticides and, through its designated State agencies, ensures that users of restricted pesticides are trained in proper use. EPA's authority is the Federal Insecticide Fungicide, and Rodenticide Act (FIFRA). FIFRA was created in 1947 as a replacement for the Insecticide Act of 1910 (Ch. 191, 36 Stat. 331 (1910)). FIFRA was amended in 1972, 1975, 1978, 1980, and 1988.

The USDA, through its Extension Service, the Soil Conservation Service, the Agricultural Research Service, and the Cooperative States Research Service, conducts research, publishes information, and offers advice used by farmers on pesticide use, land management, and agronomic practice. The SCS and the ES have been designated as co-lead agencies on the ground water issue in USDA (Spitz, 1989).

The USGS conducts ground water quality assessments and investigates temporal and spatial trends. It is examining the impact of agricultural land use on ground water quality in several areas in the pilot phase of its National Water Quality Assessment Program. In addition, the USGS recently launched its mid-continent initiative (Ragone et al., 1989). This is a 5- to 10-year

research plan that is taking a holistic approach to characterizing the total environmental fate of the widely used herbicide atrazine. Monitoring, modeling, lab research, and statistical analyses will be done to attempt a mass balance.

At the State level, pesticides are regulated by the State-led agencies (SLAs), which have been granted FIFRA primacy by EPA. Most SLAs are the agriculture departments, but there are several notable exceptions, such as the Department of Environmental Conservation in New York and Purdue University (the State Chemist's Office) in Indiana.

Public drinking water supplies are regulated in a similar manner under the Safe Drinking Water Act (SDWA). SDWA was passed in 1974 and amended in 1986. EPA in most cases has granted SDWA primacy to State health departments, but there are exceptions in this case too.

Although at the Federal level FIFRA and SDWA authority both rest in the same agency, in most States the authorities are in different agencies. This has frequently caused coordination problems in addressing pesticide contamination incidents, such as with assuming responsibilities for analysis, issuing advisory letters to well owners, and dealing with the news media. For example, at least three agencies became involved in pesticide

ground water incidents in Florida, California, Wisconsin, and other States. Thus regulatory decisions and monitoring requirements may be driven by different agencies 'marching to different drummers.' Florida and Wisconsin, at least, have addressed this problem through the creation of interagency coordination committees.

Florida's effort is called the Florida Ground Water Protection Task Force. This interagency task force was created specifically to deal with the EDB ground water crisis in 1984, and has remained in existence to deal with similar problems with other chemicals (Rhodes, 1987). Other States, such as Wisconsin, have established similar interagency task forces or coordinating committees to ensure that the agencies with pesticides and drinking water responsibilities communicate with each other.

Agencies below the State level also frequently participate in decisions and actions relevant to pesticides in ground water. For example, the Cape Cod Planning and Economic Development Commission has been heavily involved in monitoring studies and other assessments relevant to use of pesticides and fertilizers on golf courses on Cape Cod. The Suffolk County Department of Health Services has played a key role in all scientific and political activity regarding findings of aldicarb and other chemicals on

Long Island beginning in 1979 (Zaki et al., 1982). In California, three different Regional Water Quality Control Boards, eight counties, one city, one irrigation district, and one water district all submitted well sampling results to the California Department of Food & Agriculture for inclusion in its latest summary of pesticides found in well water (Cardozo et al., 1988).

Thus there is a potential to have several fingers in the regulatory pie. This idea is manifested in the remaining sections of this paper.

For a more comprehensive compilation and interpretation of State legislation in this area, see the report by Batie and Diebel (1989).

B. Reactions Affecting Product Use and Registration

The first regulatory action taken against a pesticide registration due to ground water contamination was EPA's ban of DBCP (1,2-dibromo-3-chloropropane) in the continental United States in 1979 (FR 44(219): 65135-65179, November 9, 1979; FR 46(61): 19592-19597, March 31, 1981). DBCP was a highly effective nematicide that was also very mobile, very persistent, and very toxic. It caused male reproductive effects in humans handling the

chemical and has been found in the ground water of at least five States. It was also very beneficial in pineapple, vegetable, soybean, and peach tree agriculture. It was a classic case of a chemical with high risks and high benefits. DBCP was banned only after a hard-fought battle in the hearing room between opposing attorneys and expert witnesses.

The second registration action taken in this area was when Union Carbide withdrew the registration of its product Temik (aldicarb) from Suffolk County, New York, following the 1979 growing season. Aldicarb was generally effective against the Colorado potato beetle on potato farms in this Long Island county. But aldicarb was found in 27% of 8,404 wells, with 13% exceeding the State action level (Zaki et al., 1982). Thus aldicarb use on Long Island was stopped. (Most "aldicarb" residues are actually the toxic metabolites aldicarb sulfoxide and aldicarb sulfone.)

Aldicarb is currently in the Special Review process at EPA, a public risk/benefit analysis, due to ground water and dietary concerns (FR 53(125):24630-24641, June 29, 1988). More than 30,000 wells have been sampled in the U.S. and analyzed for aldicarb.

Aldicarb was also the subject of label/use modifications in Wisconsin and Florida (Table 2). In 1981, aldicarb was found in 19% of 363 wells sampled in Portage County, Wisconsin. As a result, a series of timing, spatial, and rate restrictions were added to the pesticide's label in order to mitigate ground water contamination (Holden, 1986). In 1982, aldicarb was found in shallow ground water in Florida under an experimental plot. As a result, the State banned citrus use of the pesticide for one year and initiated two monitoring studies (Holden, 1986). After one year, aldicarb use was reinstated with significant rate, timing, and spatial restrictions designed to minimize ground water contamination. One restriction was that aldicarb should not be used within 300 horizontal feet of drinking water wells (Holden, 1986). However, subsequent studies demonstrated greater migration potential than the State had anticipated, so the buffer distance was increased to 300 meters (Jones et al., 1987). These restrictions apply mostly to the vulnerable Central Ridge area of Florida, where most of Florida's citrus is grown.

In 1983, a scenario similar to the 1979 DBCP action occurred with ethylene dibromide (EDB; 1,2-dibromoethane). All soil fumigant uses of EDB were banned by EPA following declarations of an imminent hazard and an emergency (FR 48(197):46227-46248, October 11, 1983; additional supporting data can be found in Pignatello and Cohen, in press). Like DBCP, EDB was banned because of findings in ground water and the potential for additional findings in ground water in the future. Like DBCP, EDB was mobile, persistent, and toxic. It has been detected in the ground water

Restrictions on Use of Aldicarb in Wisconsin and Florida

	Wisconsin	Florida
Rate	• Maximum 2 lbs. active ingredient per acre	• Maximum 5 lbs active ingredient per acre
Timing	• Maximum 1 application per 2 years • 4-6 weeks after planting	• Maximum 1 application per year • Between January 1 and April 30 for citrus growers (major users)
Spatial	• Moratorium areas defined as 1 mile radii around wells with 10 ppb aldicarb or greater	• Minimum of 300 meters lateral distance from a drinking-water well
Other	• May be applied only by a State-certified pesticide application specialist • Label must contain warning of potential for ground water contamination	• Warnings must be posted on the property and on wells near area of use • Use will be suspended in an area if concentrations of more than 10 ppb are found in drinking water

of 10 States and 4 countries and is an extremely potent animal carcinogen. Like DBCP, EDB was a highly effective nematicide. It was very beneficial to soybean, cotton, peanut, and pineapple agriculture. This was another classic case of high risks and high benefits. Unfortunately for all concerned, EDB was being used by many as a replacement for DBCP.

These are the most significant reactions impacting product use and registration which have already been taken due to ground water concerns. A new initiative has been launched by EPA that describes the strategy that will be used for future regulatory actions in this area.

EPA's proposed strategy for agricultural chemicals in ground water includes a prevention strategy and a response strategy (EPA, 1987). Its focus is on prevention through the development of State regulatory management plans. Thus the emphasis on dealing with the problem of pesticides in ground water is shifting toward State and local jurisdictions.

EPA establishes an overall policy framework for the development of the plans and lists a menu of topics that may be included in the plans. These proposals are depicted in Figures 3 and 4. The overall policy is a risk-benefit balancing approach. Protection goals are to consider the use, value, and vulnerability of the local ground water resource. EPA also proposes to use maximum contaminant levels (MCLs) as reference points for helping to determine unacceptable contamination.

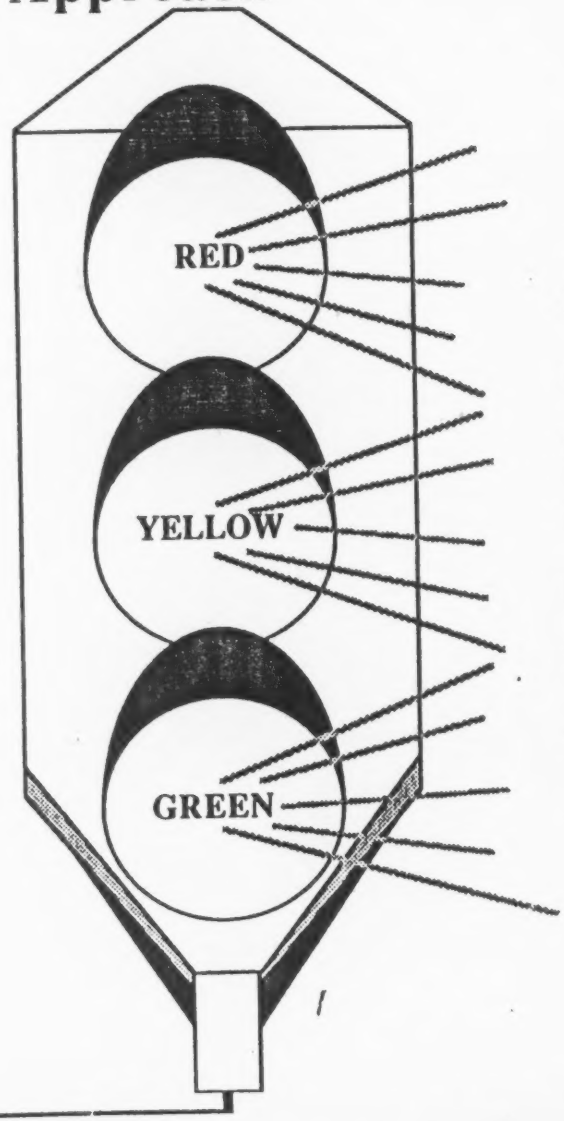
Figure 3. EPA's sliding scale of regulatory actions.

(Copied from EPA, 1987)

EPA's "Yellow Light/Red Light" Approach

Monitoring Information
- Detection Levels
- Frequency of Detection
- Trend Upward/Level/ Downward
- Scope of Contamination

Site Investigation
- Cause Determination



Menu of Management Options

National Cancellation

Regional Cancellation

Local Cancellation

Other Label Change

Enforcement Actions

Reduce Rate

Monitoring Requirements

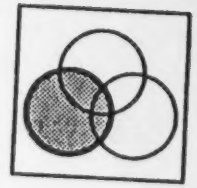
No National Requirements

E.S.C.

Figure 4. Menu of technical options available to the States under EPA's proposed strategy.

(Copied from EPA, 1987)

State Management Menu



Pesticide Use

- Moratorium Areas
- Wellhead Protection Areas
- Well Set Backs (Buffer Zones)
- Future Well Requirements: Location, Depth, Construction
- Change in Rate of Application
- Change in Timing of Application
- Change in Method of Application
- Advance Notice of Application
- Integrated Pest Management
- Best Management Practices
- Additional Monitoring
- Additional Training and Certification

EPA is planning to issue five criteria/guidance documents to implement the strategy, but funding and staffing required to produce these documents is uncertain for all but one of them (Auerbach, 1989; Jordan, 1989). The documents can be summarized as follows.

1) Minimum criteria for State ground water monitoring programs.

2) Minimum criteria for State response plans, addressing water supply, monitoring, and registration issues.

3) Criteria EPA will use to review State management plans for adequacy.

4) Criteria EPA will use to judge the post facto effectiveness of State management plans.

5) A hydrogeologic document titled Techniques for Assessing the Natural Sensitivity of Aquifers to Pesticide Contamination.

EPA's Office of Pesticide Programs proposes to produce the first four documents. EPA's Office of Ground Water Protection has funded the last project and has scheduled publication of the final report in December, 1990 (Hoffer, 1989).

EPA believes the States should have the strong role on the response issue. EPA is also considering using CERCLA and emergency powers under SDWA to remediate contaminated sites.

The proposed aldicarb regulatory decision, noted above, is the first shot out of the gun for the proposed strategy. EPA is not proposing to cancel any aldicarb uses outright. Rather, a complex hydrogeologic vulnerability assessment scheme was used to identify States or specific counties that should develop management plans. If management plans are not developed by those designated states, aldicarb use may be canceled in those States, consistent with the proposed strategy. In addition, EPA proposes 300-foot well setbacks and would require that additional monitoring be conducted by the pesticide registrant.

Thus, the time of national bans of pesticides due to ground water concerns is probably over. This strategy is being replaced by a more decentralized approach that considers statewide socio-economic and hydrogeologic variables. However, implementation of this strategy is likely to be anything but painless if EPA cannot obtain adequate funding or produce the required technical guidance in a timely fashion.

This subject is discussed further in sections III and IV below.

C. Reactions Affecting Drinking Water Consumption

The general regulatory framework pertaining to agrichemicals in ground water was described in section II(A) above. Some more specific authorities are described below, followed by some illustrative examples of people dealing with contaminated wells.

There has been very little information published in the reference literature on this subject. Therefore most of the examples listed below are based on personal experience.

The SDWA governs tap water from public water systems. Public water systems are defined as having at least 15 service connections or regularly serving an average of at least 25 individuals daily at least 60 days out of the year (40 CFR §142.2(k)). Although States such as New Jersey and Florida are increasingly establishing construction standards for private wells and monitoring wells, no State, to this writer's knowledge, can close private wells. Instead, when high concentrations of agrichemicals are reported in water from private wells, State agencies generally advise people on whether their water is suitable for drinking, cooking, or washing.

EPA and State agencies with SDWA primacy definitely have the authority to close public wells. Emergency authority is contained in § 1431, and §§ 1 15 and 1416 contain authority to grant temporary variances and waivers, respectively, to public utilities having difficulty meeting MCLs.

Finally, one authority is difficult to classify. Connecticut has the Potable Drinking Water Act (Public Act No. 85-407). This law enables the Commissioner of Health Services to issue an order to any person or municipality responsible for ground water contamination requiring them to provide potable drinking water to all persons affected by such contamination. This authority was invoked in 1984 when tobacco growers who had used EDB were ordered to supply potable water to owners of wells contaminated by the chemical.

Some illustrative examples of reactions to well contamination follow.

The Hawaii Department of Health shut down several public wells on Oahu in the summer of 1983 when EDB, DBCP, and trichloropropane were found. For a limited period of time, some of the residents of central Oahu had to obtain drinking water from a tank trunk furnished by the State. However, alternative well connections were quickly put in place which eliminated further inconvenience on the part of the citizens.

The State of Florida sends applications for remedial relief to individuals with wells containing EDB (Rhodes, 1987). If the individual requests assistance, and most do, the State evaluates the situation to determine the best solution. As of August 5, 1987, the State had installed 696 granular activated carbon (GAC)

filters and was in the process of hooking up 25 homes to existing water systems. In the State's experience, drilling of new wells has not worked. The State of Florida estimated that it had spent approximately $2.8 million in 2 recent fiscal years alone for their EDB well cleanup program.

Finally, Union Carbide (now Rhone-Poulenc) supplies 29-lb GAC cartridges to all Long Island homeowners with aldicarb concentrations in their water greater than 7 ppb (Holden, 1986). As of 1986, approximately 2,000 GAC units had been installed at a cost to the registrant of $450 each. Additionally, the registrant replaces the GAC approximately annually at an approximate cost of $60-$70 each.

Aquifer cleanup from nonpoint source contamination is likely to be very costly, as indicated by the EDB and aldicarb well cleanup costs presented above and the large number of detections indicated in section I(A). (There is no case on record when aquifer cleanup, as opposed to well or tapwater cleanup, has been attempted where nonpoint sources caused the problem.) The best solution is to prevent contamination. Barring that, the best alternatives are probably treatment at the wellhead or at the point of use, or alternative system connections.

It is clear that the Federal Government plays no role in the remediation of private water supplies, other than supplying technical information to State agencies on request.

III. Current and Potential Impacts of the Patchwork Regulatory Quilt

The discussions in section II should indicate that we are dealing with a patchwork regulatory quilt in this area. This will become more clear in this section. Sections A, B, and C describe ways in which this regulatory framework is manifested. The discussion in section D suggests that there are advantages and disadvantages to this framework.

No subjective judgments about discrepancies are being made by this author. This section is only intended to be an objective analysis.

A. Education and Certification

Certification, training, and education programs dealing with pesticides constitute an excellent example of the patchwork regulatory framework. State programs vary in terms of quality and quantity. This variation can be illustrated by a brief examination of the EPA/State programs for certifying applications.

The regulations governing certification of commercial and private pesticide applicators are contained in 40 CFR Part 171. These regulations set forth standards of types of knowledge that must be attained in order to receive certification. For example, the certification and training (C&T) programs for commercial applicators must include several types of knowledge such as safety, labeling, and the environment. Within the safety

category, several factors must be included--such as symptoms of pesticide poisoning and first aid procedures. But specific technical guidance on these topics is not specified. Therefore, States may spend 5 minutes or 5 hours on these topics, without any uniform standards for determining proficiency.

The best approach would be for EPA to require a certain degree of technical guidance as a C&T 'floor' or baseline. Then State-led agencies (SLAs) can add to the programs as appropriate for dealing with special local needs, such as chemigation, concerns unique to the citrus industry, etc.

For example, Cooperative Extension scientists from Cornell University and the University of California recently produced an education program for pesticide applicators called "Protecting Groundwater: A Guide for the Pesticide User." This program consists of a slide set storyboard and an instructor's manual. It was jointly sponsored by EPA and USDA. (Packages at $75 each are available by calling Cornell Extension at 607/255-7535.) This is an excellent package including discussions of soil properties, hydrogeology, pesticide properties, applicator practices, and health effects. Packages are being sent to the SLAs. Yet, under current regulations, EPA does not have the authority to require the SLAs and the Extension Service to include this jointly in the C&T program (Reese, 1989).

This is more a criticism of available resources than it is a criticism of EPA. It would take a significant investment of staff time--beyond what EPA can currently devote--to prepare the necessary specific technical guidance for the C&T program. (However, note the new USDA initiatives described in general terms later in this section.)

One final example may be illustrative of the situation. Between December, 1988 and January, 1989, Biospherics staff conducted a telephone poll of SLAs in California, Delaware, Illinois, Ohio, Maryland, and Virginia. The failure rate for the initial C&T test varied from 25% to 75% between States. Two of the States required no retraining for recertification, and one State required an 8-hour course for recertification.

It is also worth noting that the American Soybean Association and the National Corn Growers Association recently collaborated to produce an educational tape called "Ground Water and Agricultural Chemicals: Understanding the Issues." The tape glosses over the nonpoint source issue, but it does provide some excellent advice to prevent point source contamination. The Crop Protection Institute of Canada (6 Lansing Square, Willowdale, Ontario M2J 1T5) has produced a worthwhile booklet called "Water in Trust: Growers Guide," which also offers good advice to pesticide users.

Clearly resources exist to educate pesticide users about ground water issues. A uniform baseline program is required to transfer this knowledge.

Thus there is the need and the opportunity for the USDA to take a more aggressive role in this area. Until recently, it has been this author's opinion that many USDA headquarters officials have not been willing to support education, research, and policy efforts in this area, despite very capable and sincere efforts by field and laboratory personnel. However, this attitude seems to have changed dramatically within the last 2 years (Spitz, 1989). A soon-to-be-published report of the "Agricultural Chemicals and the Environment Work Group" will serve to synthesize ideas, suggest coordination mechanisms in this area for the massive Department, and lay the ground work for spending the $41 million USDA will be receiving to work on the issue.

B. Data Requirements

As noted in section I(B)(3) above, registrants of food-use chemicals typically have to submit to EPA results of 3 to 4 dozen studies as required by 40 CFR Part 158.

Most laboratory study results are accepted by the SLAs. However, SLAs are increasingly requiring that field studies be conducted in their State, beyond what EPA may have required. Their rationale is that field conditions in their States are either unique or significantly different. This practice is occurring quite frequently for field dissipation studies and ground water studies in California, and for ground water studies in Florida. Note that a field dissipation study package for a chemical with two major use patterns, including test and control plots, typically costs $250,000-$500,000 for sampling and analysis. One small-scale prospective ground water study typically costs $200,000-$500,000. Both cost estimates depend heavily on analytical costs and study duration.

There are rumors that other States may be heading in this direction as well.

It is this author's opinion that some degree of additional field work may be necessary, but there has to be a reasonable limit. It is unlikely that any registration could be supported if field dissipation and/or ground water studies were required in 15 or 20 States. EPA needs to supply States with the technical guidance necessary to extrapolate field and lab results to different areas of the country, within reason. This, admittedly, is a tall order to fill.

C. Regulation

Various states have been issuing their own laws and regulations regarding pesticides in ground water. Some examples follow.

In 1983, Wisconsin passed Act 410 (signed in 1984), which codified and institutionalized existing efforts on ground water quality management (Ehart et al., 1986). The law covers pesticides as well as other substances and sources. It requires the establishment of enforcement standards (ESs) equivalent to HALs or MCLs, and preventive action limits (PALs) equivalent to 1/10-1/5 the ES, depending on toxicity. Regulatory action must be taken when the ES is exceeded. Regulatory action may be taken and monitoring is generally initiated when the PAL is exceeded.

In 1985, the California legislature passed Assembly Bill 2021, the Pesticide Contamination Prevention Act. This requires the California Department of Food and Agriculture to follow exacting procedures in the investigation of any reported detections of pesticides in deep soil and ground water. These pesticides are restricted in Pesticide Management Zones (PMZs). The PMZs are defined arbitrarily as areas within approximately one square mile of wells with detections, rather than in any hydrogeologic terms.

In 1986, the Nebraska legislature passed Legislative Bill 894, which allows the State to designate Special Protection Areas (SPAs) based on proven or potential contamination by pesticides and nitrates. The purpose of LB 894 is to implement educational and best management practices in SPAs in order to reduce the potential for ground water contamination. The Nebraska Department of Environmental Control is using the ground water vulnerability index DRASTIC (Aller et. al, 1987) to help designate the SPAs. So far, the DEC has been focusing mainly on control of nitrate contamination.

In addition, the reader should keep in mind EPA's proposed strategy (section II above), which will be adding a much greater regulatory burden to many States, particularly the States with no analogous pre-existing program (Losey, 1989; Zuelsdorff, 1989). Potentially, the ultimate decentralization of authority in this case would be to defer some decisions onto farmers and turf managers based on statements on the product labeling. If that is to be the trend, someone has to be ready to educate and advise these pesticide users. If some SLAs will not be sufficiently funded, motivated, or informed to take a strong initiative in this area, the pesticide registrants and the USDA should be prepared to help fill the need. The registrants might consider developing and proposing management plans for the State to implement. The USDA

needs to increase its support for groups such as those at the University of Florida and Cornell University. These groups are in the forefront of providing useful, state-of-the-art advice to farmers in the ground water area. (New information indicates that USDA will be providing more support in this area beginning October, 1989 (Spitz, 1989).)

D. Advantages and Disadvantages

The socioeconomic factors are complex, subjective, and beyond the scope of this paper. A few comments are offered to stimulate discussion.

In any case, when preemptive regulatory actions are taken at the State or local level, it is reasonable to expect that advantages will accrue from reduced risks--assuming the alternatives are less risky--and disadvantages will accrue in terms of an inequitable economic impact on local growers or turf managers. For example, potato yields on Long Island have decreased approximately 15% since 1979 as a result of loss of aldicarb and pest infestation problems (Moyer, 1989). It is possible that loss of an efficacious pesticide, coupled with development pressures, could eventually reduce potato production on Long Island to an insignificant amount.

Differing standards of risk could prohibit use of pesticides in certain areas but not in others. For example, Wisconsin's PALs, which are 1/10-1/5 of MCLs or HALs, could have the net effect of preventing use of certain pesticides in Wisconsin, but not in surrounding States. This could be good or bad depending on one's point of view.

Additional data requirements for marginal markets could very likely cause registrants not to register or reregister their pesticides in certain States. Several representatives of the pesticide industry indicated that such a scenario is not only possible but probable.

People are quickly realizing that point source contamination caused by mishandling pesticides is a significant problem. It is also a problem that is much more solvable than the nonpoint problem. There are no disadvantages to enhancing the knowledge of pesticide users.

IV. Summary: Constraints and Opportunities

The opportunity exists to reduce significantly point source contamination of ground water by pesticides. The constraints are institutional and budgetary but they are not insurmountable.

The C&T program needs to be enhanced. Uniform technical guidance should be required by EPA and implemented by the SLAs and the Extension Service. Then States should be encouraged to build on that program 'floor,' addressing any special local needs.

In addition, EPA and the SLAs should examine the possibility of increasing use/misuse investigations in association with chemigation and mixing/loading operations.

There are no quick fixes in the nonpoint source area. EPA has proposed a strategy that is ambitious but feasible on the prevention side. It is basically sound and requires only some minor tinkering in some areas. However, there is only a narrow window of opportunity for implementation. This is because the longer it takes for implementation, the more the States will feel the pressure to implement their own strategies and/or regulations. EPA needs to be provided the technical staff and resources necessary to provide States with the technical guidance necessary to design a minimal program. If the current administration does not provide sufficient resources to EPA, pesticide registrants and USDA should consider forming a loose partnership, working with the SLAs to develop management plans that are generally consistent with EPA goals.

The USDA needs to provide more support for programs which provide one-on-one advice to farmers in this area. This author has encountered true competence and an activist spirit in the Cornell and U. Florida extension programs in this area, but a relative lack of

support by USDA headquarters, at least until recently. The recent publication of responsive research plans in this area (USDA, 1988a and 1988b) and new initiatives beginning in fiscal year 1989 (Spitz, 1989) are very encouraging developments.

EPA, USGS, and USDA should begin providing the technical guidance necessary to minimize unnecessary additional field studies in many States for the same pesticide. Otherwise, the availability of legitimate pesticides to farmers in different areas of the country could be affected.

V. Recommendations

One overriding concern is that people should not raise their expectations of what EPA can do in this area unless that agency's technical staff and budget are increased.

Following are some recommendations in no particular order.

1. Give EPA the technical staff and resources it needs to provide technical guidance and funds to the States for implementation of the proposed pesticide strategy. Otherwise, failed expectations will cause frustrations for all. Too much added work with too little technical guidance and money may cause some States to fail to submit acceptable management plans to EPA, resulting in unnecessary pesticide cancellations.

2. Give a boost to BMP research in agriculture and turf management. BMPs are likely to be an integral component of most State management plans.

3. USDA should consider reinitiating extensive, periodic, national pesticide use survey efforts to support IPM work and many other initiatives discussed in this document.

4. Encourage USDA to support and expand the technical advice it provides pesticide users in the area of ground water contamination.

5. Institute a requirement that all C&T programs use the Cornell/U.C. educational package, or something equivalent, to instruct outdoor users of pesticides. Too much flexibility is left to the States in this area. EPA should provide a minimal program floor with specific guidance. The States should have the flexibility to provide additional information to users that may reflect local conditions.

6. Authority should not be removed from the States to take independent regulatory actions against pesticides. However, the EPA program should be strengthened so that States have a high degree of confidence in the EPA program, minimizing independent actions.

7. Likewise, authority should not be removed from the States to require additional field studies. However, EPA modeling and monitoring capabilities should be strengthened (with assistance from USGS and USDA) to the point that States impose these requirements only when truly necessary.

8. EPA budget requests to enhance their capability to predict pesticide leaching should be received favorably. This could take the form of intensive field studies coupled with model development and/or validation.

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MAPPING GROUNDWATER VULNERABILITY TO AGRICULTURAL USES ON A NATIONAL SCALE IN A GEOGRAPHIC INFORMATION SYSTEM

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MAPPING GROUNDWATER VULNERABILITY TO AGRICULTURAL USES ON A NATIONAL SCALE IN A GEOGRAPHIC INFORMATION SYSTEM

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BACKGROUND AND METHODOLOGY

THE GIS DATABASE

The National Resources Inventory. In response to congressional mandates, comprehensive national surveys of agricultural and related natural resources on 1.5 billion acres of non-federal rural lands have been conducted by the Soil Conservation Service (SCS)/USDA at six different times in the last thirty years [1]. The most detailed of these inventories was the 1982 National Resources Inventory (NRI).

The 1982 NRI, collected at an estimated cost of $60 million, consists of more than 1 million individually inspected locations (sample points) configured in a statistical sampling design. At each site, nearly 200 variables describing land use and cover, conservation needs, resource condition, erosion, irrigation, conservation practices, and potential cropland as well as many other factors are assessed. In addition to the NRI information, each sample point is linked to the Soil Conservation Service's SOILS-5 databases describing physical parameters of soils, classifications and suitabilities for uses such as crop and tree production, septic fields, construction materials, and development among other factors [2].

Geographic Information Systems. Geographic Information Systems (GIS) are computer-based hardware, software and graphics capabilities that can encode, overlay, analyze and display the natural and built environment in multiple layers that are geographically registered to the earth's surface. Results of GIS analyses can be described in reports,

[1] Goebel, J.J., Dorsch, R.K. (1986). "The National Resources Inventory: A Guide for Users of 1982 NRI Data Files'. Resources Inventory Division, SCS/USDA.

[2] For descriptions, see the National Soils Handbook (1983). Soil Conservation Service/USDA.

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tables and most importantly, in maps 1

Newest and most powerful advances in computer technologies are integrating realistic simulation into displays that increase the analytical and educational power of this technology.

Figure A. shows how a GIS can be used in a simple analysis of erosion potential in a watershed.

The NRI in a GIS. The NRI was recently encoded into a national GIS database by taking advantage of the fact that each of the sample points is identified by the county -- (of which there are 3,041), the major land resource area -- (of which there are 189), and the hydrological unit or watershed -- (of which there are 2,111) in which it is located[2]. "NRI polygons" were created by overlaying each coverage on a national scale. Since the NRI is collected on non-federal lands, a federal land overlay was used to exclude them from further consideration. This process generated a GIS map base consisting of 30,000+ polygons varying in size from approximately ten square miles to a few areas of 2000+ square miles into which the NRI points are allocated. Thus the NRI attributes can be coincidentally mapped with soils information. The NRI polygon map base is shown in Figure B.

Data Sources and Map Interpretations. Most data on agricultural uses though often collected on a sub-county basis are provided only at the county level. In many cases, absolute numbers have been used because actual amounts of acreage treated, for instance with pesticides are not known. Correlations of such county-level data with sub-county NRI data should be made with care -- particularly where information like 'pounds of active ingredients of pesticides used per county' are compared with 'soils with potentials to leach' in that county. Actual pesticide use may not occur on the most vulnerable soils in that county.

Furthermore, the choropleth (thematic) mapping of polygons by single attributes (% area, for instance) generalizes information within that polygon. At the scale used here, individual polygons are nearly invisible. In any event, attributes in polygons should be treated as describing trends across multi-polygon areas and usually not within single polygons.

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[1] Maizel, M. (1985). A National Survey of Geographic Information Systems for Natural Resources Decision Making. The American Farmland Trust, Washington, D.C.

[2] White, D., M. Maizel, K. Chan, J.Corson-Rikert (1989). "Polygon Overlay to Support Point Sample Mapping: The National Resources Inventory". AUTO-CARTO 9. Baltimore, Maryland

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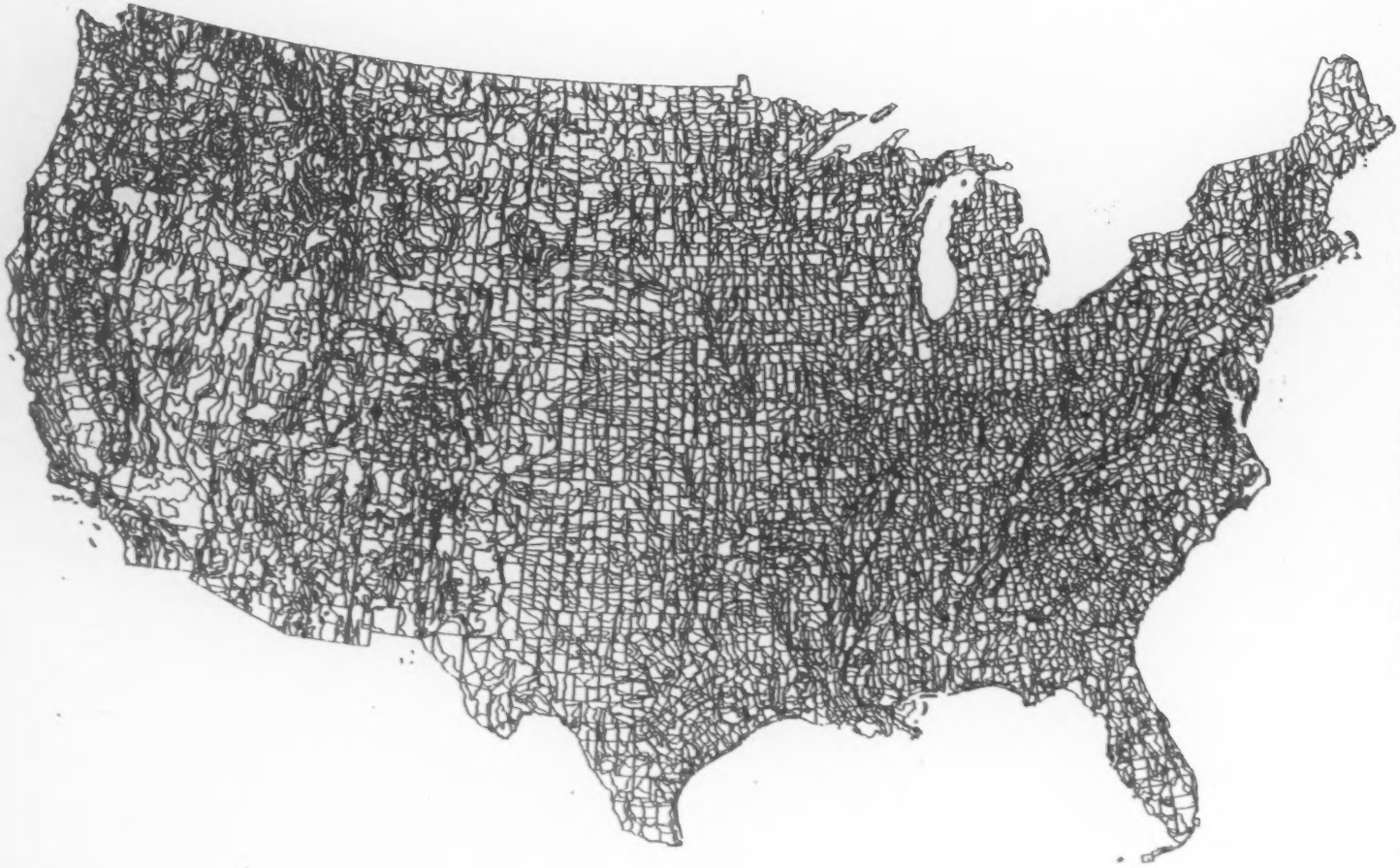
FIGURE 9.03 NATIONAL RESOURCES INVENTORY MAP BASE GENERATED BY POLYGON OVERLAY



In contrast, however, combinations of SOILS-5 information with NRI land use data such as, for instance, "cropland on soils with a high potential to leach" as determined at inventoried sample points represent true coincidences of land use with soils potentials at those specific sites. Individually digitized NRI points -- not currently available -- could produce sub-polygon segregation of attributes.

The Authors. This study is a product of an on-going collaboration started at the American Farmland Trust in 1985 with the Harvard Laboratory for Computer Graphics and Spatial Analysis to help deliver GIS technologies to local, regional and national decision makers. The GIS program is now operated under the National Center for Resource Innovations, a nonprofit, tax-exempt educational organization with other Centers in Georgia and Arkansas.

Computer systems. Computer systems at the Harvard Laboratory for Computer Graphics and Spatial Analysis include an IBM mainframe for selection of data from tapes, a VAX workstation for data processing and a UNIX-based Concurrent Computer 5450 workstation at the Center for Resource Innovations, Washington D.C. for data integration and assembly in maps. Software included ODYSSEY, ROOTS (a digitizing and data exchange program) and custom programming. Map output was on a Tektronix 4693DX 300 dots per inch thermal printer.

BACKGROUND AND RESULTS

FACTORS IN GROUND AND SURFACE WATER VULNERABILITY:

Ground and surface water vulnerability is a product of interrelationships between natural resources and agricultural uses. Examples of some general agricultural uses include:

- types of cropland
- animal confinement operations
- pesticide use
- fertilizer use, and
- irrigation

Physiographical components of the natural resource base affected by these uses involve:

- soils
- geology and
- hydrology as well as
- combinations of the above

In most cases, soils are the primary interface between agricultural systems and water resources. This report concentrates on the use/soil/water relationship.

Soils Potentials as a model for estimating impacts to surface and ground water resources. Soils, in most cases are the primary interface between agricultural land uses and water resources. Using computer modeling, the Soil Conservation Service/USDA recently developed algorithms that allow classification of soils according to their potential to behave in association with pesticides [1] and by analogy, nitrates.

Factors used to determine these 'soils potentials' include:

(1) Hydrologic Soil Groups incorporating:

- soil permeability,
- average depth to water table of the soil layer
- drainage, and
- depth to slowly permeable layers

(2) as may be affected by:

[1] Goss, D.W. (1988). Pesticide-Soil Interaction: Potentials for Loss. Soil Conservation Service/USDA

- organic matter content and
- depth of the surface layer of soils.

Hydrologic Groups are classifications of soils into four groups --A through D--, (Table 1.). The main factor in this classification is the inherent capacity of the soil without vegetation to permit infiltration. Group A soils have a high infiltration rate when thoroughly wet and have a low runoff potential. They are mainly deep, well drained and sandy or gravelly. Soils in group D at the other extreme have a very slow infiltration rate and thus have a high run off potential. They also have a permanent high water table or are shallow over nearly impervious bedrock or other material. Soils can be assigned to two hydrologic groups if part of the soils are drained and part undrained.

Determining Soils Potentials to leach. The algorithms for soils potentials to leach are:

High:

If hydrologic Group = A
and organic Matter times horizon #1 depth
<=30 or
If Hydrologic Group = B
and Organic Matter times horizon #1 depth
<=5

Nominal:

If hydrologic group = A and
Organic Matter times horizon #1 depth >= 65 or
If hydrologic Group = B and
Organic Matter times horizon # 1 depth > = 45 or
If Hydrologic Group = C or
If hydrologic group = D

Intermediate:

Everything else

note: those soils classified as having a dual hydrologic group (soils which through drainage have been converted from a D or E hydrologic group to a higher permeability group) were classified according to the latter group.

'Soils potentials' are thus 'values' ordered into a hierarchy and allocated to groups described as high, intermediate or nominal potentials to leach and/or to allow losses of pesticides (and nitrates by analogy) from soils surfaces. In fact, these potentials describe the principal mode by which ground or surface water resources can become contaminated. For this study, only soils potentials to leach are mapped.

HYDROLOGIC GROUPS

Rating Property	A	B	C	D
Soil Drainage Class	Excessively or well (moderately well for deep sands)	Well or moderately well	Moderately well or somewhat poorly	Poorly or very poorly
Depth to restrictive layer (slowly permeable bedrock, fragipan or ortstein)	Very deep > 50"	Deep 40-50"	Moderately deep 20-40"	Shallow 0-20"
Average depth to high water table	> 50"	40-50"	20-40"	0-20"
Permeability (in/hr)	Upper 20" >2.0 Below 0.6-20 [very rapid, rapid, moderately rapid]	Upper 20" > .6-2 Below >.2 [moderate in upper part]	.06-.60 slow or moderately slow, same depths as restrictive layer	<0.06 Same depths as restrictive layer

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Factors not included in soils potentials ratings. Soils potentials are determined independently of actual climate, vegetation, applications methodologies, cropping systems and other factors which can influence availability, activity and half-lives of pesticides. Though SCS provides ways to incorporate some of these factors at the farm field level these factors are not included here.

Other Factors affecting soils potentials. Whatever the potentials for soiis leaching or surface losses of pesticides may be, they can be overridden or affected significantly by:

- slopes greater than 15%
- presence of surface Organic Matter Layers
- Shallow or perched Water Tables
- Lithic Soil Subgroups [1]

SCS provides guidance to the local analyst for ways to consider these factors in potentials estimates [2] at the local level, also.

Pesticide Leaching and surface run off potentials. In addition to rating soils, SCS and ARS/USDA have also ranked pesticides classing them into groups with large, medium and small potentials to leach and/or to run off by accounting for half-lives, solubility and organic matter partitioning coefficients. By matching soils potentials with pesticide potentials, SCS has provided ways to assess specific relationship between soils and pesticides [3] as agricultural uses. Twenty-five pesticides on which 'use' information is available are listed in Table 2.

RESULTS AND DISCUSSION

SOILS POTENTIALS TO LEACH AS A PRIMARY FACTOR IN GROUNDWATER VULNERABILITY.

Potential vulnerability of water resources can theoretically be estimated by correlating intrinsic vulnerability of the natural resource base (soils, geology and hydrology, for instance) with general agricultural uses such as cropland, county level data on nitrogen produced by animal confinement facilities, and the use of fertilizers and pesticides which leach.

[1] Goss, D.W. (1988). Pesticide-Soil Interaction: Potentials for Loss. Soil Conservation Service/USDA

[2] See Field Office Technical Guides (FOTG) for States. Soil Conservation Service/USDA

[3] Goss, D.W. (1989). Soil and Pesticide Information for Implementing Water Quality. Soil Conservation Service/USDA.

RATINGS OF PESTICIDES TO LEACH OR RUN-OFF

CHEMICAL	POTENTIAL	
	Run off	Leach
Atrazine	M	L
Alachlor	M	M
Acifluorfen	M	M(Na+)
Bensulide	L/E	S/E
Trifluralin	L	S
2,4-D	S	M
Carbaryl	M	S
Carbofuran	S	L
Malathion	S	S
Cyanazine	M	M
Parathion	L/E	S/E
Propanil	S	S
Chlorothalonil	L	S
Diazinon	M/E	M/E
Disulfoton	M	S
Ethoprop	M	L
Fluometuron	M	M
Methamidophos	S	L
Methyl Parathion	M	S
Metiram	L/G	S/G
Metolachlor	M	M
PCNB	L/E	S/E
Phorate	L	S
Thiobencarb	M	S
Vernolate	M	S

L = Large
M = Medium
S = Small

Source:
Resources for the Future/Use
D. Goss, ARS,SCS/USDA/Potentials

Soils potentials to leach pesticides (and by analogy, nitrates) are presented here as a potentially central factor determining availability of pesticides (and nitrates) to ground and surface water resources. Some of those factors cited by SCS as affecting these potentials such as KARST topography, and shallow high water tables are also shown as examples to illustrate opportunities for identifying on a geographical basis, certain problem areas and targeting general kinds of conservation practices and programs that could lead to mitigation of problems.

It is not the intent of this study to illustrate all relevant factors which could play roles in actual water resource vulnerability. Further, no attempt is made to 'weight' the influence of shallow water tables, or KARST topography or other factors. Rather, these factors are described separately since they vary signficantly in geographic locations. Information about vegetative cover, actual climatic factors and interstitial (geologic) layers between soils and aquifers are not incorporated at this level of analysis.

Organic matter content of soils is changeable according to season and cropping systems and may significantly influence leaching potentials for soils. Data used describing organic matter is fixed in these algorithms as that present when the NRI was conducted in 1982.

Correlation between potentials to leach, agricultural uses and groundwater data.

Soils potentials to leach pesticides together with other intrinsic principal factors which may influence leaching potentials, in this GIS can be used to characterize general regions of similarity (Figs 1 through 16). A pair of such similar areas, for instance are in the "driftless" area of southwest Wisconsin and the smaller Lancaster-Lebanon-York County region of southeastern Pennsylvania, for instance.

A comparison of surface and ground water quality data with potential vulnerability would be an effective means by which to test predictions about vulnerabilities and to estimate the relative roles played in that vulnerability by specific land uses and modifying factors.

Visual inspection of patterns in well data showing nitrate levels as collected by the USGS Geological Survey [1] suggests that there may indeed be some relationship between vulnerability patterns as expressed

[1] Committee on the Role of Alternative Farming Methods in Modern Production Agriculture (1989). Board of Agriculture, National Research Council, National Academy Press, Washington, D.C.

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by leaching potentials, and factors such as KARST topography and high water tables; agricultural uses (as cropland, fertilizer and pesticide use and nitrogen produced by confinement operations) -- Figures 11-16 -- and water quality.

For instance,

- the amount of land area in soils with potentials for leaching in North Central Iowa is lower than that found in either the northeastern or northwestern corners of the state (Fig 1). In north-central Iowa water quality problems may be influenced by shallow water tables (Fig.3) Patterns of elevated nitrate levels in wells corresponding to leaching potentials and high levels of agricultural uses are higher in the northeast and northwest corners of the state [1].

- patterns of high nitrates in wells in the "driftless" area of Wisconsin correlate with potential vulnerability also as described by high levels of nitrogen production from confinement facilities,(Fig 12) cropland on which significant amounts of fertilizer are used (Fig 13) (and significant use of pesticides which leach also occurs (Fig 11) and places where more than 25% of the land area is cropland on soils with high or intermediate potentials to leach (Fig 14). Furthermore, the "driftless" area is underlain by shallow depths to bedrock (data not shown) which is KARST topography (Fig 15). In the driftless area, however, seasonal high water table appears not to be a major problem (Figs 3 and 16).

- A complementary profile exists for the physiographically similar region in Lancaster-Lebanon-York counties in southeastern Pennsylvania where the agricultural uses are similar, physiographic problems are strikingly similar and nitrate levels in wells are correspondingly elevated [1].

- A broad 'S'-shaped curve of soils with peaching potentials, Karst topography, cropland, confinement operations, fertilizer and pesticide uses starting in North Dakota, moving south threough South Dakota then through eastern Nebraska and through western Kansas, Oklahoma and Texas (Figs 1-16) is broadly associated with patterns of elevated nitrate in wells [1].

Of course, in order to satisfactorily test these relationships, computer-based correlations would be required -- providing available

[1] Alternative Agriculture (1990). Committee on the Role of Alternative Farming Methods in Modern Production Agriculture, Board on Agriculture National Research Council, Washington, D.C.

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data are adequate.

The Possibility of Using Factors contributing to vulnerability to identify mitigation programs. Conservation and best management practices are designed to address certain kinds of resource problems and potentials for certain modes of contamination can assist in targeting programs by geographic area and priority-setting of conservation agendas.

For example,

- in northeast-central Indiana, KARST underlies extensive cropland areas at some level below the soils layer (Fig 15). The principal vulnerability problem in the region for pesticide use is one of shallow water tables (Figs 3 and 16) where most of the soils are in hydrologic group C (data not shown). Thus the mode by which water resources would become contaminated in this area would be principally through surface losses -- likely promoted by the high water table and/or relatively impermeable layer(s) in the soil. (Local or state soils surveys would delineate these factors).

On the other hand,

- in southern Indiana, where cropland occupies less land area (Fig 10), the principal potential groundwater problem appears to to be associated with shallow depths to bedrock (data not shown) which is KARST topography (Fig 15). Groundwater protection in these areas might relate to sinkholes and the potential for direct contamination of groundwater supply.

- in the south eastern coastal plain of the country , where cropland is less extensive, the principal threat to water resources seems to be due to shallow water tables (Fig 3) rather than through soils with a high or intermediate potential to leach pesticides (Fig 1). In this area, high levels or organic matter (data not shown) may be providing strong mitigation of potentials to leach.

SOILS POTENTIALS, RELATED FACTORS AND SPECIFIC AGRICULTURAL USES COMPARED WITH DRASTIC AS MODELS FOR POTENTIAL GROUNDWATER CONTAMINATION.

DRASTIC is an empirical model used to estimate ground water contamination potential [1]. DRASTIC factors include:

- depth to water table,

[1] Aller, L., et al., DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings. EPA/600/2-85/018

- net recharge,
- aquifer media,
- soil media,
- topography,
- vadose zone impacts, and
- hydraulic conductivity of the aquifer.

Each factor is assigned a rating and the rating is then 'weighted' to develop a DRASTIC score. The DRASTIC score indicates relative potential for groundwater vulnerability at the county or regional level.

Scoping the potential for water resource vulnerability resulting from agricultural land uses: soils potential for water resource contamination and DRASTIC. DRASTIC has provided a useful interim model with which to estimate potential groundwater vulnerability in that it cites some general factors which should be considered in assessing vulnerability potentials. However DRASTIC is scaled to work in at the regional or county level only and cannot be used effectively at the farm field, state, or national levels in a comprehensive or uniform manner. Furthermore, DRASTIC cannot be used in modeling or simulating watershed-based relationships between land-based impacts and transportation of those impacts off-site.

Soils and their potentials on the other hand are specifically designed for this kind of scoping and modeling.

Potentials and Uses. Using resources within their 'carrying capacity' is an acceptable conservation ethic that if followed is expected to lead to sustainability of the nation's food-producing and related natural resources. Conservation practices are also recognized as optimizing sustainability of resources for future uses. Agricultural uses are integral to the concept of vulnerability in rural areas since most of the nation's non-federal natural resources are affected by some form of agricultural use or have to potential to become so. Certain agricultural uses and practices may be accommodated well in some regions and others may not.

Because DRASTIC contains no "use" factors, correlations between uses, intrinsic vulnerabilities and water quality cannot be made. Thus no options for alternatives to those uses or problem mitigation through conservation practices are available to the model.

Soils potentials offer these options.

Comparing DRASTIC and Agricultural Use/Soils Potentials/water resource vulnerability Relationships. Significant differences in vulnerabilities

using DRASTIC are easily detectable by comparing a national DRASTIC map[1] and[2] with different combinations of vulnerability potentials and agricultural use (Figures 1 through 16). For example DRASTIC maps indicate there is no problem in the "driftless" area of southwestern Wisconsin. Soils potentials to leach in this region are rather high, and bedrock (in this case, KARST topography with fissures, tubes and caves up to 1000 feet long and 50 ft high) is within five feet of the surface. Agricultural uses include cropland, confinement operations producing >2000 tns/yr. nitrogen and use of leaching pesticides in excess of 100 tns/yr. per county. Seasonal high water table is not a problem though erosion on cropland apparently is since much of the cropland is eligible for, and enrolled in the CRP (Fig 16).

Similarly, DRASTIC indicates there is no problem in the northwest and northeast corners of IOWA, in eastern South Dakota, or in Ohio and elsewhere. Comparisons between analyses above and well data indicate otherwise and of course areas of similarity are also evident.

Soils potentials for specifically-modeled uses: the use-soils-water interface. Soils are the primary interface between water and agricultural uses except where water resources are directly affected. Thus soils potentials for specific uses therefore are likely to have the greatest effect on water resources from agricultural impacts.

The approach of the Soil Conservation Service in using soils potentials for specific uses is not a new concept for SCS. For years they have provided SOILS-5 information on use potentials, suitabilities and use potentials such as for septic fields, animal waste disposal, water resource protection, habitat components and crop production[3]. What is new is the specific modeling provided by recent work[4] and[5]. By estimating specific soil-pesticide -nitrate, -potassium interactions based on modeling, and by providing matrices to estimate these interactions[6], SCS is laying the appropriate foundation for addition of other factors

[1] Crutchfield, S., and K. Algozin, (1989). "U.S. Agriculture and Water Quality: Scope and Extent of the Problem". Economic Research Service, USDA.

[2] Agricultural Resources: Cropland, Waterr and Conservation Situation and Outlook, (1989). Resources and Technology Division, Economic Research Service, U.S. Dept. of Agriculture, AR-16.

[3] National soils handbook (1983). Soil Conservation Service/USDA

[4] D. Goss, (1988). Pesticide-soil interaction: Potentials for Loss. National Soil Survey Center, Soil Conservation Service, USDA.

[5] D. Goss (1988). Soil-Pesticide Interaction Ratings. National Soils Handbook, SCS/USDA

[6] D. Goss (1989). Soil and pesticide information for implementing water quality. Addendum to the National Soils Handbook, SCS/USDA

and relevant simulation of causal relationships. This should lead to solutions for alternatives and/or mitigation of potential impacts of farm systems on water resources.

Computer technologies using simulation and modeling in Geographic Information Systems makes this even more available and potentially more widely usable.

CONCLUSIONS

Identification of factors related to groundwater vulerability. It appears that specific kinds of vulnerability problems can be identified from national scale maps on a regional basis. On this basis, then, general types of conservation measures, research and data gathering agendas might be targeted. It is important to note, however, that these analyses in particular are asking that areas with high levels of specific or dominant characteristics be identified. (The data are expressed as "percent areas that have a high percentage of attributes.

> Several factors may contribute equally to an attribute such as for instance, situations where soils in three different hydrologic soils groups are present in equal amounts (each 1/3 of the land base). No single factor would be displayed as a dominant feature amounting to more than 33%. Of course these statistics can be handled differently to display such conditions but as shown here, this should be considered in selecting regions by attribute as shown here.

Soils Potential to leach as a possible pointer to potentials for groundwater vulnerability at the national scale. Naturally, soils potentials to leach and other factors as a model for groundwater vulnerability may only be a part of the picture. Nevertheless, at a national scale this factor in concert with agricultural uses may be sufficient to identify vulnerable ground and surface water regions to some extent. Many questions remain, but even if all factors can be accounted for, one question -- an interesting and important one -- is "at what level of detail do various factors such as vegetation, climate, crop cover and farming systems enter the equation and at what levels and how do corollary policies interact ?"

Opportunities to test this on a national-to-local continuum are available. A GIS compatible with the one used here developed by the University of Wisconsin for the state to assess ground and surface water vulnerabilities contains many of the factors (and conservation programs) cited here as potentially important in water resource modeling.

Selection of Conservation Measures. Whether specific types of Best Management Practices for water resource protection can be targeted from national scale maps may be open to question. Theoretically, classes of best management practices which protect shallow water tables or surface water bodies impacted by surface losses of pesticides would be different from those designed for minimizing leaching potential.

However, assessing the potential for priority-setting and targeting of conservation provisions to regionally specific resource areas using GIS technologies, establishing specifications and standards for data collection and descriptions, at national, state and local levels to assist in specifically addressing water resource protection, and designing research agendas should be explored.

A Conservation Title for the 1990 Farm Bill Focussed on Ground and Surface water protection. The most intensively managed agricultural resource is the nation's 341 million acres of cropland. The 1985 CRP, as focussed on potentially highly erodible cropland for many reasons including eligibility, rental rates tied to lower-value commodities and other reasons benefited principally the Great Plains Region. USDA's investments of $1.2 billion for cost sharing practices and 10-year contract commitments amounting to approximately $18 billion [1] are significant.

There is some overlap in areas where cropland is eligible for the CRP and cropland that is associated with soils potentials to leach (Fig 16). Thus enrolment in the CRP may indeed be protecting water resources -- not only through removing sediment loadings, but also from leaching chemicals by removing opportunities for their use on retired croplands.

A focus on cropland -- and thus on pesticide and fertilizer use -- on soils with potentials to affect water resources through leaching of pesticides and/or nitrates for example, would shift eligibility for Farm conservation programs at least,-- and potentially significant funding -- from the Great Plains Region into the high production cropping and livestock regions of the corn belt (Figure 16).

In many regions, intensive animal confinement operations coincide with cropland. New attention to nutrient wastes in these areas would also benefit ground and surface water quality.

[1] "Logo Piece" (1990). Summary Report for the CRP, first through Ninth Sign-ups. Agricultural Stabilization and Conservation Service/USDA.

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MAP LEGENDS.

1. PERCENT AREA SOILS WITH HIGH OR INTERMEDIATE LEACHING POTENTIAL.

Soils with high or intermediate potential to leach as modified by surface soils layer depth and organic matter were combined and mapped through the NRI sample points to the GIS map base. "Hatched" areas indicate the location of federal lands.

2. PERCENT AREA SOILS WITH HIGH/INTERMEDIATE POTENTIAL TO LEACH WHERE KARST OR KARST-LIKE TOPOGRAPHY IS FOUND

Soils with a high or intermediate potential to leach overlying KARST or KARST-like topography are mapped. "Hatched" areas indicate the location of federal lands.

note: KARST may be at, or near the surface in some areas such as the "driftless" area in south western Wisconsin and in northern Lancaster county, Pennsylvania. It may also be as much as 2-300 feet below the surface in other areas but still represent a kind of vulnerability to groundwater.

3. PERCENT AREA SOILS WITH AVERAGE SEASONAL HIGH WATER TABLE LESS THAN SIX FEET FROM THE SURFACE.

Soils with an average seasonal high water table less than six feet from the surface are mapped to the NRI database. "Hatched" areas indicate the location of federal lands.

4. PERCENT AREA SOILS WITH POTENTIAL TO LEACH WHERE KARST OR KARST-LIKE TOPOGRAPHY IS FOUND.

Soils with a high or intermediate potential to leach where mapped as associated with Karst or Karst-like topography. "Hatched" areas indicate the location of federal lands.

Note: as in above, depths of KARST areas can vary from being at the surface to several hundred feet below it.

5. USE OF TWENTY-FIVE PESTICIDES BY COUNTY (1984-85).

County level information about pesticide use was obtained from Resources for the Future [1] on diskette. Amounts used ranged in 1984-85

[1] L. Gianessi, Resources for the Future (1989). Personal communication.

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from none in many counties to 1.6 million pounds in Palm Beach County, Florida. "Hatched" areas indicate the location of federal lands.

6. PESTICIDES WITH LARGE OR MEDIUM POTENTIALS TO LEACH

County level information about pesticide use is from Resources for the Future [1]. These twenty-five Pesticides account for more than one-half of the active ingredients in pesticides used in the country. Farmland include all farmland for this analysis excepting forestland. Potentials to leach were determined by SCS/ARS, USDA [1]. These were rated by the Soil Conservation Service/USDA according to their potential (large, medium or small) to leach. "Hatched" areas indicate federal lands.

7. NITROGEN PRODUCTION FROM CONFINEMENT OPERATIONS

County level livestock inventories for 1982 (Agricultural Census) were used to determine nutrient production factors on an annual basis (Sweeten, OTA,1990). For each of dairy cows and heifers [.106 tns/hd/yr], hogs and pigs [.013 tns/hd/yr], poultry (including broilers [.0004 tns/hd/yr], chicks [.0006 tns/hd/yr], pullets [.0006 tns/hd/yr], turkeys [.0002 tns/hd/yr]) and feedlot operations [.049 tns/hd/yr].

8. ATRAZINE: A PESTICIDE WITH A LARGE POTENTIAL TO LEACH County level data source: Resources for the Future. Amounts range from nothing in some counties to 1.2 million pounds in Palm Beach County, Florida.

9. ACRES OF FARMLAND TREATED WITH COMMERCIAL FERTILIZER
County level Data source: U.S. Census of Agriculture.

10. PERCENT AREA CROPLAND. "Hatched" areas indicate the location of federal lands.

11. PERCENT AREA SOILS WITH HIGH OR INTERMEDIATE POTENTIAL TO LEACH IN COUNTIES WHERE MORE THAN 100 TONS/YR OF PESTICIDES WHICH LEACH ARE USED.

Counties where more than 100 tons of active ingredients (200,000 lbs) of pesticides were used in 1984-5 were selected and soils potential to leach in these counties mapped. Maximum amount used was in Palm Beach County (700 tons/yr). Most pesticides inventoried are used on cropland.

12. PERCENT AREA SOILS WITH POTENTIAL TO LEACH IN COUNTIES WHERE MORE

[1] D. Goss, (1989). Pesticide-Soil Interaction -- Potentials for Loss National Soil Survey Center, Soil Conservation Service/USDA

THAN 2000 TNS/YR NITROGEN IS PRODUCED BY CONFINEMENT OPERATIONS

Counties where more than 2000 tns/yr nitrogen is produced by confinement operations were selected and soils with high or intermediate potentials to leach were mapped.

13. PERCENT AREA SOILS WITH A HIGH OR INTERMEDIATE POTENTIAL TO LEACH IN COUNTIES WHERE MORE THAN 150,000 acres OF FARMLAND IS TREATED WITH FERTILIZER.

Data are available on amounts of fertilizer used from the Tennessee Valley Authority but coverage by state is not complete.

14. PERCENT AREA CROPLAND ON SOILS WITH A HIGH OR INTERMEDIATE POTENTIAL TO LEACH.

Places where more than 25% of the land area is in cropland on soils with a high or intermediate potential to leach are shown mapped on the NRI polygon map base.

15. PERCENT AREA CROPLAND WHERE KARST OR KARST-LIKE TOPOGRAPHY IS FOUND

Four general groups of KARST characterized by the extent of fissures, tubes and caves and KARST-like features[1] as described by the US Geological Survey are combined here in one 'KARST' group and mapped with cropland. Cropland is a major agricultural land use of 341 million non-federal acres as identified in the National Resources Inventory. "Hatched" areas are federal lands

Note: KARST topography can vary in depth from being at or close to the surface as it is in the "driftless" area in Wisconsin to being several hundred feet below it as in northern Florida or Georgia (data not shown). "Hatched" areas indicate the location of federal lands.

16. PERCENT AREA SOILS WITH MINIMUM DEPTH TO SEASONAL HIGH WATER TABLE LESS THAN TWO FEET IN COUNTIES WHERE MORE THAN 100 TNS/YR LEACHING PESTICIDES ARE USED.

Water tables which rise into root zones of crops can significantly increase leaching of pesticides. Soils with high water tables rising into the top 24 inches of soils are mapped in counties where more than 100 tns/yr leaching pesticides are used.

[1] Engineering Aspects of KARST (1984). U.S. Geological Survey National Map Atlas Series

SUMMARY LISTING OF BLACK AND WHITE PUBLISHING QUALITY MAPS PREPARED

	Original number
A. Intrinsic Vulnerability	
1) Percent area Soils with High or Intermediate Leaching Potential	1)
2) Percent Area Soils with High/Intermediate Potential to Leach Where KARST or KARST-like Topography is Found	3)
3) Percent Area Soils with High Water Table Less Than Six Feet Below the Surface	4)
B. Agrichemical Uses	
5) Use of Twenty-five Pesticides by County	5)
6) Pesticides with Large or Medium Potentials to Leach	6)
7) Nitrogen Production from Confinement Operations	7)
8) Atrazine: a Pesticide with a Large Potential to Leach	8)
9) Acres on Which Commercial Fertilizer Used	9)
C. Cropland	
10) Percent Area Cropland	Extra
D. Combinations	
11) Percent Area Soils with Potential to Leach in Counties where More Than 100 Tons Per Year Leaching Pesticides are used	10)
12) Percent Area Soils with Potential to Leach in Counties Where More Than 2000 tons/yr. Nitrogen Produced by Confinement Operations	11)
13) Percent Area Soils with Potentials to Leach Where More Than 150,000 Acres of Farmland are Treated with Commercial Fertilizer	12)
14) Percent Cropland on Soils with High/Intermediate Leaching Potential	Extra
15) Percent Area Cropland Where KARST or KARST-like Topography is Found	2)
16) Percent Area Soils with High Water Table Less Than Two Feet Below the Surface in Counties Where More Than 100 Tons/yr. Leaching Pesticides are Used	13)
E. Policy use demonstration	
17) Cropland Eligible for the CRP and Cropland on Soils with a High or Intermediate Leaching Potential	14)

FARMSTEAD ASSESSMENTS: A MEANS TO MANAGE FARM SOURCES OF GROUNDWATER CONTAMINATION

by

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Author(s) name(s), Contract paper title, prepared for the U.S. Congress, Office of Technology Assessment, *Beneath the Bottom Line: Agricultural Approaches To Reduce Agrichemical Contamination of Groundwater* OTA-F-418 (Washington DC: U.S. Government Printing Office, November 1990).

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ABSTRACT

In recent years agriculture has been linked to contamination of groundwater with nitrate, pesticides, pathogenic bacteria and other pollutants. Public attention has focused on contamination caused by application of fertilizer, pesticides and livestock wastes to cropland. Insufficient consideration has been given to the potential for farmstead structures and practices to cause groundwater contamination.

A farmstead refers to the area centered on the farm residence. A farmstead typically includes barns, barnyards, and silos; structures for storage and handling of pesticides, fertilizers and petroleum products; and potable water wells. Management and maintenance of farmstead structures can have a significant effect on the quality of groundwater and the farm's well water.

A farmstead groundwater pollution assessment (farmstead assessment) is a tool to (1) identify potential farmstead sources of groundwater contamination, (2) educate farmers about management practices to prevent groundwater contamination, and (3) point out to the farmer relevant laws, regulations and sources of assistance.

Such an assessment is not without precedent. Home energy audits, offered by utilities in all states under federal legislation, afford a model for farmstead pollution assessments. Energy audits addressed a national concern (fossil fuel shortages) and assumed a motivation of self-interest (reducing utility bills) to achieve a societal goal (reduced energy use). Similarly, the farmstead assessment could help achieve a societal goal (groundwater protection) by focusing on farmers' self-interest in protecting their well water. Other assessment procedures also suggest elements that could be incorporated in a farmstead assessment.

Development of farmstead assessment techniques is underway in several states. As described in this paper, a farmstead assessment would include:

1. Evaluation of soil, geologic and hydrologic factors affecting groundwater pollution potential from the farmstead.

2. Evaluation of farmstead structures and activities affecting pollution potential (e.g., pesticide and fertilizer handling and storage, manure storage and handling, septic system and well location and maintenance, petroleum products storage and handling).

3. Use of a standardized format to integrate the site evaluation and evaluations of farmstead structures and activities, resulting in a detailed report of groundwater pollution potential and suggested structural and management changes to minimize pollution.

Policy issues focus on how to implement the farmstead assessment concept (i.e., who will do it; who will pay for it) include (1) providing assistance to farmers, through Cooperative Extension Service and the Soil Conservation Service, to conduct farmstead assessments; (2) requiring the agrichemical industry to provide assistance with farmstead assessment; (3) requiring existing pesticide applicator training programs to incorporate farmstead assessment procedures; (4) require farmstead assessments as part of existing Soil Conservation Service farm conservation plans; and (5) including farmstead assessments in a national nonpoint source regulatory program. Developing a successful farmstead groundwater pollution potential assessment will likely involve some combination of these policy options.

FARMSTEAD ASSESSMENTS -- A MEANS TO MANAGE FARM SOURCES OF GROUNDWATER CONTAMINATION

INTRODUCTION

Increased documentation that agricultural practices are causing contamination of groundwater with nitrate, pesticides, and harmful bacteria has led to increased interest in protecting groundwater. Insufficient consideration has been given to potential for farmstead practices and structures to cause groundwater contamination.

In this report a farmstead refers to the area centered on the farm residence. A farmstead typically includes barns, silos and related farm buildings; structures and facilities used for storage and handling of household waste, livestock waste, pesticides, fertilizers and petroleum products; and potable water wells for human and livestock use. Management and maintenance of these structures and facilities have a major influence on the quality of groundwater in general and the farm's well water in particular.

A formal farmstead pollution potential assessment would (1) identify real and potential sources of contaminated well water, (2) educate the farmer concerning appropriate structures and management practices to correct or prevent pollution problems, and (3) point out relevant laws and regulations affecting the farmstead, possible regulatory infractions and possible sources of assistance in correcting the infractions.

A farmstead assessment would benefit both the farm family and society as a whole. Virtually all farm families rely on private wells as their sole source of drinking water. They are the most directly affected by contamination of the water supply from farmstead activities, and have the most to gain from identifying and adopting practices to protect that water supply. Most practices that keep pollutants out of the farm well water will also help protect the larger groundwater resource that many non-farm households and businesses rely on for potable water. Finally, by increasing awareness of the relationship between farmstead practices and groundwater quality, the farmstead assessment will be one step toward a broader goal of increasing farmers' understanding of and commitment to water quality and other conservation values. A basic assumption of the farmstead assessment is that information and education are the essential first steps in pollution prevention.

As described in this paper, a farmstead assessment would include three steps:

1. Evaluation of soil, geologic and hydrologic conditions to identify the pollution potential of the individual farmstead site;

2. Evaluation of farmstead structures and activities affecting pollution potential. These would include well design and location; pesticide handling, storage and disposal; fertilizer handling and storage; livestock waste storage facilities and management; silage storage facilities and management; petroleum products storage and disposal;

septic system location and management; farm and household hazardous waste disposal and recycling; and milkhouse waste handling.

3. Integration of the site pollution vulnerability evaluation with the pollution potential from farmstead structures and activities. The result would be an assessment of farmstead groundwater pollution potential, and suggested structural and management changes to reduce existing or potential pollution.

The information and procedures to assess pollution potential from specific practices under specific site conditions are technical, time consuming and expensive. Farmers will need technical and financial assistance to conduct the assessment. The assessment procedure described in this paper assumes that assistance will be provided by public or private personnel trained in the assessment procedure, and through a series of "self-help" fact sheets.

Development of a workable farmstead assessment is underway in several states. Key policy questions center on <u>implementation</u> of the concept: Who should use the assessment procedure? Should it be voluntary or mandatory? Who should pay for the farmstead assessment and suggested changes in farmstead structures?

This paper evaluates the concept of the farmstead assessment as a means to protect groundwater, and highlights some of the key policy options for implementing the concept. Specifically, the paper describes (1) key farmstead elements affecting pollution potential, (2) the elements of a practical

farmstead assessment procedure, (3) similar assessment models, (4) incentives and constraints to development and use of a farmstead assessment, and (5) policy options for implementing the farmstead assessment concept.

Several points should be made about the scope and limitations of this paper. First, this paper emphasizes practices that will protect the farm's well water. In most cases, such as improving pesticide handling practices to minimize spills, the practices will help protect the larger groundwater resource. In other cases, such as proper installation and maintenance of the well itself, the practices might protect the farm's well water but not groundwater in general.

Second, this paper does not address the broad issue of the use of agrichemicals on cropland and their impacts on groundwater. The focus of this paper is on farmstead management. However, it is assumed that farmstead management practices to protect water quality should be only one part of a larger effort to integrate water quality considerations into agricultural management and agricultural support systems (e.g., soil testing, crop consulting, USDA programs).

Third, the policy options identified in this paper do not represent an exhaustive list. Policies to implement a farmstead assessment procedure will certainly include a combination of the options identified here and perhaps others not identified. In addition, it is not within the scope of this paper to offer detailed analyses of the economic and social implications of the suggested policy options.

Finally, it is not essential for purposes of this paper to identify farmstead groundwater pollution sources as either point or nonpoint sources. In reality, some farmstead pollution sources could be considered nonpoint sources (e.g., surface runoff contaminating an improperly sealed well), while others could be considered point sources (e.g., nitrate leaching to groundwater from beneath a manure storage area).

FARMSTEAD FACTORS AFFECTING GROUNDWATER POLLUTION POTENTIAL

A farmstead pollution assessment will need to analyze four factors: (1) physical site factors, (2) the characteristics of potential pollutants (3) how potential pollutants are handled and produced on the farm, and (4) well design, location, and management. Factors one and two are addressed in detail in another document in this overall OTA report. This section of the farmstead assessment report analyzes on-farm handling and management of potential pollutants including the design, location, and management of farmstead structures and activities that are potential sources of pollutants; and well design, location, and management.

Pollution Potential From Materials Produced, Handled and Stored on the Farm

Pesticides and Nitrate

Characteristics

The nitrate form of nitrogen is a common contaminant in groundwater in agricultural areas of the United States (Hallberg, 1986; Nielsen and Lee, 1987). Nitrate in well water has caused illness and even death in infants (Johnson and Bonrud, 1988) and can also affect livestock health (Jackson et al., 1983). Because soil solids are negatively charged, nitrate is not attracted to colloid surfaces and moves freely with percolating water (Keeney, 1986). Farmstead sources of nitrate to groundwater include livestock waste, nitrogen fertilizer storage, septic systems and stored silage.

The EPA has identified more than 30 pesticides with characteristics that make them susceptible to leaching and groundwater contamination (Nielsen and Lee, 1987). An increasing number of pesticides are being detected in groundwater in numerous states. Detection has largely been a function of the intensity of monitoring efforts (Hallberg, 1986). The health effects of long-term exposure to low levels of pesticides in groundwater are unclear, but concerns are focused on possible risks of cancer, impaired immune functions and reproductive problems (Cantor, et. al., 1987). Farmstead sources of pesticides are primarily areas where the chemicals are handled (i.e., areas used for mixing, loading, and storage).

Farmstead Structures and Management Practices Affecting Pollution Potential From Pesticides and Fertilizer

Pesticide and fertilizer spills and leaks at commercial facilities have been responsible for numerous detections of chemicals in groundwater (Hallberg, 1986). In some cases pesticide concentrations in soils and water around pesticide mixing, loading and equipment cleaning areas are close to formulation concentrations (Hallberg, 1986; North Carolina State University, 1985; Table 1). On-farm storage, mixing and loading areas can present a similar, although smaller scale, threat to groundwater. For example, a typical pesticide field application rate is one to four pounds per acre. Spilling 1/4 lb of a chemical in a 100 sq. ft area around a wellhead is equivalent to the application of 100 lbs per acre. Improper management of on-farm mixing and loading areas is believed to be a major factor causing farm well water contamination to exceed enforcement

standards of alachor (Lasso) and atrazine (Ehart, personal communication, December 23, 1988). When pesticide concentrations exceed 50 micrograms per liter in well water, mixing, loading, storage and disposal sites should be suspected and investigated (Klaseus, et al., 1988).

Storage. Pesticide labels contain brief but explicit instructions for storage. Ideally, pesticide containers should be stored in a separate fire-resistant facility on a raised pallet or on a raised and drained concrete platform (Jackson et al., 1987). Most farmers use existing buildings for pesticide storage, although the buildings have not necessarily been designed for that purpose. If these buildings have an earthen or wooden floor, spills or leaks present a groundwater contamination threat, particularly if they are located in areas of permeable soils and fractured bedrock, or near a well. Guidelines for safe storage facilities are available (e.g., Doersch et al., 1988; McBride and Fanning, 1986). Detailed plans for a pesticide storage and mixing building are available from the Midwest Plan Service, Ames, Iowa, 50011.

Mixing/loading areas. Pesticides and fertilizers are commonly loaded and mixed at the same location on the farm. Often the site is near a well for convenience in filling spray tanks (Voss et al., 1987). The same site is sometimes used to rinse equipment after an application. As a result, chemical residues can accumulate in soils and are available for leaching to groundwater (Doersch et al., 1988). Concrete pads and water-tight dikes can contain spills and allow recovery of the spilled chemical. If the concrete pad slopes to a collection basin, the same area can be used for rinsing application equipment.

Transfer systems. Some systems for loading, transferring and mixing pesticides eliminate the need to open containers and handle materials, and thus reduce the chance for spilled materials or rinse water to contaminate groundwater. Such systems meter and transfer chemicals from the shipping container to the mixing or application tanks and often rinse the emptied container (Bohmont, 1983). Individual farmers have developed a variety of ways to use couplings, valves and hoses to transfer and mix chemicals in a closed system (Reichenberger and Guebert, 1983).

Disposal practices. Three types of pesticide waste with potential to contaminate groundwater are produced on the farm: leftover pesticides, empty containers, and rinse water from washing equipment and containers.

Some pesticides are listed as hazardous or acutely hazardous wastes in the federal Resource Conservation and Recovery Act. Many other pesticides not specifically listed in federal and state laws are classified as hazardous because they exhibit hazardous characteristics identified in the laws (Jackson et al., 1987; Wachs and Hamel, 1987).

Pesticide containers that appear empty generally contain chemical residues. For example, several ounces of some pesticide formulations can remain in an unrinsed 5-gallon container despite the best efforts to empty it (Doersch et al., 1988). Some residues remain even after draining and rinsing (Table 2). Triple rinsed containers can be legally disposed of in sanitary landfills, but fewer landfills are accepting them because of liability concerns.

Rinse water from cleaning application equipment and containers also contains chemical residues. Rinse water includes solutions left after field spraying, water from washing the outside of the sprayer or spray tank, and spray left in booms and hoses. Rinse water should be sprayed on fields at the proper rate of application for the chemical; often it is simply dumped or left on the ground (Voss et al., 1987). A number of facilities have been designed and tested for disposing of leftover pesticides and rinse water (U.S. EPA, 1986). These disposal systems might be feasible for use at commercial facilities, but there is a continuing need for inexpensive systems for use on farms (Voss et al., 1987).

Livestock Waste

Characteristics

Nitrate and pathogenic microorganisms from livestock wastes can accumulate in the soil and leach to groundwater (CAST, 1985). Nitrate accumulation occurs under barnyards, feedlots and storage areas where manure accumulates, and under fields where large amounts of manure are spread. The principles of nitrate movement with water through soils apply to nitrogen in manure as well as nitrate in nitrogen fertilizers.

More than 150 diseases can be transmitted from animals to people; the microorganisms that cause many of these diseases are found in manure. Most microorganisms in water entering the soil are effectively filtered or

do not compete successfully with indigenous soil organisms (Peterson et al., 1984). However, the occurrence of large soil pores or thin soils over fractured bedrock provide a pathway for entrance of pathogens into groundwater. Surface runoff of animal wastes into improperly sealed wells can be a major source of pathogens in well water (CAST, 1985).

Farmstead Structures and Management Practices Affecting Pollution Potential from Livestock Waste

Livestock waste storage and handling. The design, location and management of permanent and temporary livestock waste storage facilities are factors in causing or preventing well water contamination by nitrate and bacteria (CAST, 1985). Storage and handling facilities will minimize leaching if they are constructed of concrete or other impermeable materials and properly managed. Management includes routinely inspecting and maintaining above-ground systems to insure that they do not rupture, filling facilities only according to design specifications, and, most important, applying the stored wastes according to a livestock waste utilization plan. Such plans maximize crop use of nutrients and minimize water quality impacts by identifying the proper rate, time and location for spreading wastes on the land.

Locating the facility down-gradient from the well further reduces the potential for well contamination if the storage system fails or overflows. Improper design or location of facilities can result in contaminated surface water running past or ponding by the well. Storage

facilities that are abandoned, when partially or completely full, can present high pollution risks. This may occur as a result of property sales, foreclosures, or owner health problems that result in sale of farm equipment and livestock. Wastes left in these facilities will continue to decompose, making large quantities of nitrate available to leach or runoff. Storage facility liners also break down over time.

Livestock holding areas. As with manure storage facilities, the location of concentrated livestock holding areas such as barnyards and feedlots affects the potential for bacteria and nitrate contamination of groundwater. Locating facilities down-gradient from wells, for surface water and groundwater flow (if known) can reduce the potential for well contamination from farmstead sources. Soil compaction in constantly used livestock holding areas often restricts water infiltration. When livestock holding areas are temporarily or permanently abandoned, the compacted soils will be loosened by natural biological and climatic processes. This increases the rate of organic matter decomposition and the rate of water infiltration. High concentrations of nitrate will be available as a result of decomposition of the organic wastes that have been mixed with the soil over the years. As the rate of water infiltration increases, the potential for well water contamination also increases.

Silage

Characteristics

Corn, legumes and grasses are commonly stored in moist, partially fermented conditions for use as livestock feed. When stored in silos and other facilities, these wet crops are compacted, and lose moisture which drains out of the silo as effluent. Effluent production from silage varies with the material stored, its moisture and nitrogen content, and handling and storage. Of these, moisture appears to be the most crucial. Several researchers have concluded that materials stored at 65% moisture content or higher can produce effluent. For grass silage, the amount produced varies from a trickle at 75% moisture to 79 gallons per ton at 85% (Stewart, 1979). About three-quarters of the effluent is produced in the first three weeks of storage, although it can continue to flow for up to three months.

The composition of the effluent varies with the material stored. This liquid is often highly acidic and can be corrosive to concrete and steel (Tang, et al., 1988).

In Britain, high levels of bacteria, "black water" and hydrogen sulfide smells resulting from tower silo effluent have been reported in well water. Pit storage of canning company wastes in Wisconsin has caused several cases of ground and surface water contamination. Several cases of groundwater contamination with effluent from pit silos have occurred in

Wisconsin. Groundwater contaminated with silage effluent has a disagreeable odor and shows increased levels of acidity, ammonia, nitrates, and iron. In one case, thousands of gallons of sweet corn silage juices drained through a limestone sink hole and contaminated wells a mile from the site (Wisconsin Department of Natural Resources, 1983 and 1986).

Farmstead Structures and Management Factors Affecting Pollution Potential from Silage

When properly harvested and stored, silage poses little or no pollution threat (Odgers, personal communication, 1989). Improper silage handling can lead to significant effluent flow from storage facilities. Silage is frequently stored on uncovered ground or in structures with potential to leak silage juices (Jackson et al., 1987). Silage storage facilities include vertical silos, trench silos, temporary stacks and temporary plastic storage tubes. None of these facilities or storage practices were designed for the purpose of groundwater protection. Locating facilities down-gradient of wells and as far away from wells as practical will reduce pollution potential. Collection of silage effluent in facilities that prevent leaching will also reduce pollution potential. These can include water retention structures such as clay or plastic lined ponds (Woolford, 1978).

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Farmers can use several methods to reduce effluent production from silage. They can vary their cutting and harvesting times, cut or crimp the material, add a silage preservative such as formic acid, or add moisture absorbent materials to the silage as it is stored (Woolford, 1978). The most effective of these is allowing the material to wilt in the field for 24 hours. Although this may not always be possible in humid climates, it has been shown to reduce moisture content by 10 percent and effluent production by 100 percent (Woolford, 1978). Adding absorbent materials has also been shown to be effective, both in reducing effluent and in raising the nutrient value of the silage.

Household and Milkhouse Waste Water

Characteristics

Septic systems are the most frequently reported source of groundwater contamination on a local level (OTA, 1984). Household septic systems, if improperly sited, overloaded, improperly used or poorly functioning, can contribute contaminants derived from human wastes and household cleaners to the groundwater. These contaminants include nitrate, chloride, bacteria, viruses, and organic and inorganic chemicals (Aller et al., 1985).

Soil absorption fields are also the conventional disposal method for milking center wastewater. Components of milkhouse wastewater are manure, feed and other solids on the milkhouse floor, and detergents and

sanitizing agents used in cleaning (Bates and Machmeier, 1985). Decomposing milk fats and solids often clog soil/water infiltration channels and cause the system to fail. Factors involved in absorption field clogging are:

- sanitizers used in cleaning can reduce the bacterial action in the septic tank;
- increased daily volumes of water do not allow adequate detention time in septic tank;
- occasional spills of whole milk are flushed through the septic tank and quickly plug the absorption field;
- manure solids from the milking parlor or holding area are flushed through the septic tank and quickly plug the absorption field.

The volume of waste to be treated and the soil's capacity to attenuate organic wastes are critical (Holmes, personal communication, November 23, 1988; White and Brugger, 1981). Soil absorption fields for milkhouse waste disposal are not covered specifically by state regulations, and dairy inspections require only that liquid waste be disposed of in a sanitary manner (Wisconsin Department of Agriculture, Trade, and Consumer Protection, 1981). Although soil absorption fields for milkhouse waste disposal can be addressed as part of a thorough Grade A dairy inspection, such inspections are likely to focus on surface discharges of milkhouse wastes and resulting attraction of insects and animals, rather than potential for groundwater contamination.

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Farmstead Structures and Management Practices Affecting Pollution Potential from Household and Milkhouse Waste Water

Septic systems. Factors affecting contamination potential from septic systems include density of septic systems, soil and hydrologic conditions, and construction and age of the system. These systems can be designed and located to give adequate protection to groundwater. Guidelines are available for proper use and maintenance (e.g., Wisconsin Department of Natural Resources, 1987; Appendix A).

Milkhouse systems. Many of the same design and location factors that apply to household septic systems apply to soil absorption systems for milkhouse waste treatment. To ensure proper treatment of milkhouse wastes, farmers should consider building a separate wastewater treatment facility, or pumping the waste into a livestock waste storage facility. Alternating wastewater flow between two soil absorption fields is also possible (Holmes, personal communication, November 23, 1988). Milkhouse wastes can also be effectively treated on the ground surface or stored in a lagoon (Bates and Machmeier, 1985). However, expenses for modifying existing systems may be prohibitive for smaller dairy operations and operations with cash flow problems.

Petroleum Products

Characteristics

Gasoline and oil are stored on farms in both above-ground and below ground storage tanks. Petroleum products contain benzene, xylene, toluene

and other organic compounds that have contaminated groundwater in many areas of the country. Leaking storage tanks have been identified as a major source of these contaminants (U.S. GAO, 1988).

Petroleum products might pose health risks equal to or greater than risks related to pesticide contamination. For example, the groundwater enforcement standard in Wisconsin for benzene is 0.67 parts per billion (ppb). Of the commonly used pesticides, only alachlor (Lasso) has a lower state standard (Wisconsin Groundwater Coordinating Council, 1988).

Farmstead Structures and Management Practices Affecting Pollution Potential from Petroleum Products

Below ground fuel tanks. U.S. EPA has noted that the most numerous underground storage tanks are those used for gasoline and fuel oil. Many farms have their own storage of petroleum products for farm vehicle use (Aller, et al., 1985). Often leaks are undetected until contamination shows up in wells of farms or the neighbors (Walsh, 1984).

There are four primary causes of leaks from underground storage systems: 1) corrosion, 2) chemical incompatibility, 3) improper installation, and 4) poor operating practices. The rate at which each problem can initiate leaking is affected by the physical environment in which the tank is situated and the materials from which tanks are constructed. For example, of the two primary materials from which tanks are made, unprotected steel is subject to rusting or corrosion by various materials, and fiberglass may crack or be slowly dissolved by alcohol blends.

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Many farmers are exempt from federal regulations on design and operation of underground storage tanks (Federal Register, September 23, 1988). Regulations in some states are not expected to allow this farmer exemption. Regardless of regulatory status, however, the large volume of hazardous materials that can be released from storage to cause groundwater contamination in a small area poses a high on-site risk, and a farmer would not be exempt from liability for spill cleanup.

Groundwater pollution can be minimized by proper tank design and placement, properly placed monitoring wells, frequent inspections, fluid level monitoring, use of spill prevention devices, and replacement of older tanks (those older than 10 to 15 years which may have begun to leak).

Above ground fuel tanks. Above ground storage tanks can potentially cause the same problems as underground tanks. Undetected, slow leaks due to corrosion of the tank bottom placed directly on the ground are possible (Goldsmith, personal communication, 1989). Also, above ground tanks often have below-ground distribution lines. Some of the same management factors that apply to underground storage tanks are applicable.

Oil, grease, and solvent storage and disposal. Although quantities of these petroleum based products stored on the farm are probably less than gasoline and fuel oil in above ground or below ground tanks, amounts are usually greater on a farm than in a typical residential area. The pollution potential of these substances depends on: (1) type of containers

used for storage, (2) spill frequency, (3) disposal practices, (4) nature of surface where stored (whether paved or bare ground for example), (5) whether or not storage is in covered area, (6) the nature of the petroleum products and their mobility in soils, and (7, location and frequency of vehicle maintenance activities and other activities which may result in spills or improper disposal of petroleum products such as antifreeze, oil, and transmission fluid.

Well Design, Location, and Management

In addition to drawing water up from an aquifer, a well can also be a direct conduit for pollutants at the surface to move down to groundwater. Proper well design, location, and management are important factors in the protection of a farm's potable water supply.

Design Factors

If the well casing is open or not water tight at the top, contaminated surface water can enter the well or the space between well casing and soil around it. In cases where the well penetrates more than one aquifer, if the casing is not properly grouted for the well's full depth it could increase the potential for interchange of contaminated water between shallow and deep aquifers.

Location and Management Factors

Location of wells in clay soils provide the most effective natural protection of groundwater. To help ensure potable water, wells should also be located reasonable distances from potential sources of groundwater contamination. State or local well codes specify minimum separating distances for some farmstead activities and structures. In general, wells should also be located as far as possible from potential sources of groundwater contamination.

Wells should also be located so that surface and subsurface drainage does not transport pollutants to the well; that is, they should be located upgradient of potential sources of contamination. If the direction of groundwater flow is not known or cannot easily be determined, locating new wells so that pollution sources are between the well and the nearest surface water body increases the likelihood of well protection, since in most cases groundwater flows toward surface waters. Wells should not be located in flood plains or areas where ponding is likely.

In some cases, distances of structures or activities from the well can be increased. For example, pesticide mixing and loading areas, gas tanks or short term manure stacks could be relocated to areas that pose lower pollution risks. If distances between wells and potential sources of groundwater contamination cannot be changed, farmers can improve their management of the potentially polluting facility or activity. For example, if a silage storage facility is too close to the well according

to the state separation distance recommendations, a farmer might install a system to collect silage effluent and prevent it from leaching to groundwater. Similarly, livestock traffic could be directed away from the well.

One of the most important well management activities is to have the water tested periodically to ensure that it is safe to drink, and to save and compare test results. Other management practices include: (1) checking the well cap or seal to ensure that it is in place and tightly secured, (2) installing backflow prevention devices between the well and a pesticide sprayer to prevent backsiphoning of chemicals into the well, and (3) monitoring changes in local land uses beyond the farm and their potential for causing groundwater contamination.

Non-potable Water Wells

Some types of wells other than potable water wells are unique and require special attention. Livestock watering wells vary widely in design and location. They are often in livestock holding areas and thus close to livestock wastes, which can be significant sources of nitrate and bacterial contamination. Groundwater contamination is also possible from irrigation wells, because chemicals are commonly applied through irrigation systems. If back-flow preventors are not installed and maintained, these chemicals may flow back into the well and enter the groundwater system (Hay and Eisenhauer, 1985).

Abandoned Wells and Other Potential Contamination Conduits

Improperly abandoned wells may allow contaminated surface water to reach the groundwater, or for vertical movement of contamination from one aquifer to another. The EPA has noted that abandoned wells commonly provide conduits for the migration of contaminated water (U.S. EPA, February, 1988). The water might be surface water that enters through the open conduit, water migrating from a zone of undesirable water quality into a drinking water aquifer. When a well is abandoned, the casing is often removed from the ground or allowed to deteriorate to the point that casing leaks develop. This readily permits fluids under pressure to migrate, upward or downward, and contaminate the aquifers (Aller, et. al., 1985). Contamination from abandoned wells and water wells was noted by a significant number of states, territories, and the District of Columbia (U.S. GAO, 1988). Many state and local well codes specify abandonment procedures. Proper well abandonment often requires pressure grouting, and blocking casing perforations to adequately seal off different aquifers and prevent movement of water through annular (between the casing and the drillhole) spaces. Abandonment might also involve removal of the well casing or the pump above the ground (U.S. EPA, February, 1988). Abandoned drillholes (e.g., from an unsuccessful attempt to construct or reconstruct a well) might also provide a conduit for migration of contaminated water.

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EXISTING ASSESSMENT MODELS

The concept of a farmstead assessment is not without precedent. A number of other assessment procedures have been developed to help farmers or homeowners improve management of their lands and buildings and protect resources of national interest. Some of the assumptions behind these assessments and elements of their operation are germane to a farmstead groundwater pollution assessment procedure, and are discussed below.

Residential Energy Audits

This existing national program requires states to develop and implement residential energy conservation plans. If states did not take required actions, the Department of Energy implemented basic federal requirements within the states. Implementation of this program enables individuals to obtain audits of their home energy consumption and provides recommendations on how to reduce consumption; sources of assistance to make needed improvements; and sources of financial assistance available to facilitate installment of improvements. The "Conservation Service Reform Act of 1986" (PL 99-412) provides the most comprehensive model for how a farm assessment program might work. This program began in 1978.

The National Energy Conservation Policy Act of 1978 required major utilities in all states to offer on-site home energy inspections by qualified auditors. Underlying this requirement was the belief that use of the audits and resulting recommendations to provide information on

likely costs and resulting savings of energy improvements would lead customers to make the improvements recommended by the audits (U.S. DOE, 1987). Under a typical program the auditor: (1) inspects the exterior, basement, attic, and living space, (2) analyzes the costs and potential savings of applicable energy conservation measures, (3) furnishes information about inexpensive energy conservation practices, and (4) makes arrangements upon request for purchase, installation, financing, and billing of energy conservation and renewable resource measures, with appropriate attention given to consumer protection (Wisconsin Division of State Energy, 1984). The program is funded primarily but indirectly by utility rate payers. In effect, all rate payers contribute to a typical home energy audit system, although relatively few take advantage of the service offered. The federal program ends in 1989, but states have the option of continuing their programs. In many states, utilities have institutionalized the program (Jones, personal communication, November 9, 1988).

Several elements of the energy audit program might be relevant to a farm pollution assessment. First, while a national concern (fossil fuel shortages) prompted action, the program took advantage of homeowners' economic self-interest (reducing utility bills) to achieve the larger societal benefit. Similarly, the farm pollution assessment could help achieve a societal goal (groundwater protection) by focusing on farmers' clear interest in clean drinking water. If incentives for farmers to take voluntary actions are ever to be effective, it is likely to be in the area of groundwater protection because farmers are the most directly affected (Nielsen and Lee, 1987).

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Second, the energy audit relied on technical experts conducting the assessment and helping homeowners understand the results and take follow-up action. These experts were not available in adequate numbers for the implementation of the program. This required the development of systematic evaluation procedures, and a program to train staff to implement those procedures. Because groundwater pollution potential and possible remedial actions are complex, a similar approach of technical assistance to landowners for assessment and remedial action might be appropriate.

Third, because society as a whole benefits from energy conservation, the energy audit program spread the cost among all rate payers, rather than directly charging users of the service. A similar funding concept might be appropriate for the farm pollution assessment. It could be based on Iowa's experience, in which fees and taxes on agricultural chemicals are being used to support research and related educational programs directed toward reducing negative environmental impacts of agricultural practices (Hallberg, et al., 1987).

Many other specific points related to the organizational structure and implementation of the Residential Conservation Service Program could aid in designing and implementing a farm pollution potential assessment program. Program organization and implementation factors relevant to the farm pollution potential assessment are contained in Public Law 99-412, the Wisconsin Residential Conservation Service State Plan and the 1987 General and Summary Reports to Congress on the Residential Conservation Service Programs. Some relevant points include:

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1. Larger utilities are required to offer an energy audit service,

2. Smaller utility installers, contractors and suppliers can voluntarily participate (i.e., offer similar audit services) upon successful application to the state administering agency,

3. The energy audit not only identifies possible energy savings, but provides assistance in arranging for installation and or financing,

4. Oversight of the firms conducting the audits are provided through annual reports required by the state "entity that certifies a plan." The report must include: (a) data on the number of buildings receiving benefits, (b) estimates of energy savings resulting from improvements, (c) detailed description of benefits, (d) names of entities carrying out plans, (e) identification of most effective plans, and (f) a statement on the number of low and moderate income individuals receiving benefits.

5. The Comptroller General is required to report to Congress annually. The Secretary of Energy gathers information for the report. This information includes: (a) costs of programs, (b) benefits of programs, and (c) information on modifications that could improve cost-effectiveness.

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6. The Department of Energy is responsible for administration of the program in states that do not assume this responsibility.

7. Participation has been relatively high with groups that received higher benefits from energy savings. Individuals and groups with less to gain from long-term energy improvements (e.g., renters, elderly, moderate to low income groups) were less likely to participate.

8. Amendments to the program have greatly increased the flexibility of states and utilities to design their own programs to meet established energy saving goals. In general, the increased flexibility resulted in improved program effectiveness. The most effective program implementation is occurring in states where the state and participating utilities are tailoring programs to serve customer needs.

9. The 1978 founding legislation, discussed earlier, contains sunset dates after which individual states and utilities can continue the program, although federal requirements and support end.

The 1987 General and Summary Report to Congress identified that about 6 million of a potential 77 million residences requested energy audit assistance. Several states had nearly 20% participation. High participation rates seem to be related to the commitment of the states and the participating utilities.

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Farm Bureau Self-Help Checklist

The Groundwater and Environmental Pollution Self-Help Checklist, completed in 1987 by the Natural and Environmental Resources Division of the American Farm Bureau Federation, is intended to be filled out or reviewed by farmers annually. The checklist solicits basic information about water supply and testing, climate and soils; potential of farm activities to pollute groundwater and drinking water; off site assessment of potential sources; storage of agricultural chemicals; handling and application of agricultural chemicals and container disposal. It provides instruction for taking a water sample, recommends individual actions, and suggests local farm bureau activities (American Farm Bureau Federation, 1988; Appendix B).

The checklist incorporates the principal factors relevant to groundwater pollution potential, and in doing so provides a preliminary educational tool for improving a landowner's awareness of groundwater and how his or her management affects groundwater quality. However, a major drawback of the "self-help" checklist is that there is no technical support readily available to help the landowner interpret results of the checklist, set priorities for action, or improve management to solve problems suggested in the checklist. The Farm Bureau recommends that the checklist be used at "safe drinking water clinics," where farmers could fill out the checklist and afterwards ask an expert about potential problems and remedies. After using the checklist to identify groundwater pollution vulnerability, the Farm Bureau suggests that farmers obtain

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local technical assistance to reduce the potential for groundwater contamination (Porterfield, personal communication, November 2, 1988). No structured, integrated program of local assistance to support use of the checklist has been contemplated nationally.

SCS Farm Planning/Erosion Control Process

The USDA Soil Conservation Service (SCS) has assisted farmers in developing farm conservation plans for at least 50 years. SCS and local conservation district staff assess farm soil and topographic characteristics and cropping practices. This information is used to develop estimates of erosion potential for different fields. Based on this site assessment and advice on available options from local government conservation staff, the landowner or operator adopts a plan that specifies management and structural practices needed to bring erosion levels down to the established standards. In some cases, the conservation plan includes recommendations for improving management of other resources, such as wildlife habitat, stream corridors, livestock waste, or woodlots.

No estimate of groundwater pollution potential is currently available from this process. However, farm planning is an established mechanism familiar to farmers for assessing certain farm resource problems. It might be appropriate to expand the erosion assessment process to include groundwater pollution potential. However, deficiencies exist both in staff training and assessment tools. SCS staff and other local soil conservation staff traditionally have been trained in the processes and

management of soil erosion, not in hydrogeologic processes or the relationship of agricultural management practices to groundwater protection. In addition, there is no groundwater equivalent to the Universal Soil Loss Equation; that is, an accepted model using standard values and readily available data to produce a simple, quick, reasonably accurate assessment of groundwater pollution potential.

Farm conservation plans contain certain incentives to encourage compliance. Adoption of a farm plan is linked to federal farm program benefits. The conservation compliance provisions of the 1985 Food Security Act require many farmers to have an approved farm erosion control plan by 1990, and to implement the plan by 1995. To remain eligible for most USDA program benefits, farmers must develop and be actively applying a locally approved conservation plan for highly erodible fields (U.S. EPA, April, 1988). The "cross-compliance" concept might be applicable to a farmstead assessment. However, cross-compliance would be more difficult to apply to groundwater protection than to cropland erosion practices. For example, farmer compliance with such practices as improving pesticide loading and mixing procedures or managing a livestock waste storage facility would not be obvious from a spot check of the farm.

Another incentive to farm plan adoption is the cost-sharing that is frequently available from federal and state agencies. Cost-sharing helps landowners pay for such improvements as constructing cropland grassed waterways or contour strips. If the farm groundwater pollution assessment is a voluntary process, cost-sharing might be another incentive to adopt certain costly improvements such as improved chemical storage facilities.

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Grade A Dairy Inspections

Sanitary inspections of Grade A dairy farms are required by the federal Pasteurized Milk Ordinance (PMO). The PMO was initially developed by the Food and Drug Administration (FDA) in the Department of Health and Social Services in the 1950s. It has been regularly updated to reflect technological advances. States which adopt and implement the PMO (and economic conditions are such that all states do) have a program of on-farm sanitary inspections that occurs every six months. Compliance is checked annually by FDA representatives. The survey evaluates building construction, condition of dairying equipment, sanitation of the barn and milking parlor, and tests for bacterial content of livestock well-water (Daggs, personal communication, 1988; Wisconsin Department of Agriculture, Trade, and Consumer Protection, 1988). Aspects of building construction evaluated include floor type, grade and drain; condition of windows and doors; and adequacy of lighting and ventilation.

Although the program is focused on sanitation and milk quality rather than environmental quality, the program's focus on well water testing might be incorporated into a farm groundwater pollution assessment. Starting the farm pollution assessment with a water test might be a useful way to gain a landowner's interest. Although there may not always be good correlation between the test result and the pollution potential on a particular farm, conducting the test would be an appropriate beginning of an educational program on the link between farm management and groundwater quality.

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Other Relevant Work

Other projects or programs are underway that involve some assessment of farmstead activities, and experience is being gained that may facilitate acceptance of the type of farm assessment system proposed by this report. Although this section cannot reference all relevant state agricultural assessment programs, some deserve at least brief mention here.

In northeastern Wisconsin, a cooperative, public and private organization one-year project is underway to identify sources of stray voltage (unwanted escape of electrical voltage from circuits) in dairy operations. It is suspected that this stray voltage can cause decreased milk production and deterioration of herd health. One hundred randomly selected farmers are visited quarterly to determine whether or not a stray voltage problem exists and to provide potential sources of technical and financial assistance for any remedial actions (Hendrickson, personal communication, December 5, 1988).

Another project which includes a farm assessment component is the Wisconsin dairy well water quality testing project. The Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) is sampling wells at randomly chosen Grade A dairy wells to investigate the presence of agricultural pesticides and nitrate-nitrogen in the state's groundwater. When pesticides are found in the water at levels above state groundwater standards, DATCP conducts an on farm assessment to try to determine the cause of the contamination (LeMasters, personal communication, November 7, 1988).

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In Kansas, the Department of Health and Environment in cooperation with Kansas State University is developing a predictive modeling technique to estimate well water quality using information about farmstead activities. A series of educational materials is being developed to enable farmers and others to use the techniques to estimate well water quality, and make informal decisions on locating pollutant sources and protecting well water quality (Powell, personal communication, March 20, 1989).

Conclusions

Expertise and experience are being developed in the assessment of groundwater pollution potential from farmstead activities. However, current efforts are lacking the support system needed to (1) educate farmers to the link between farmstead activities and groundwater contamination, (2) demonstrate the long-term management changes needed to protect groundwater, and (3) provide financial and technical support to make the changes. Several environmental or farm assessment programs suggest elements that might be incorporated into a successful farm pollution assessment program. These elements include a voluntary approach, technical assistance throughout the process (from problem assessment to selection of remedial actions), costs distributed among a broader group than just the users, incorporation of incentives (e.g. cost-sharing) and disincentives (e.g. loss of certain benefits) to encourage cooperation with the program, and linking of the assessment procedure to a well water testing program.

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ORGANIZING THE FARM POLLUTION POTENTIAL ASSESSMENT PLANNING AND MANAGEMENT TOOL

Farmstead Assessments

Components

Individual farmers do not have, and are not likely to develop, the technical ability to evaluate pollution risks associated with the wide range of activities that they are involved with every day. The farmstead pollution potential assessment tool and delivery system should therefore assist farmers in evaluating their farmsteads, with technical assistance when necessary. The farmstead assessment system should have five major components:

1. procedures to diagram the location of farmstead buildings and determine the direction of groundwater flow;

2. site evaluation procedures to determine relative pollution vulnerability based on soil, geologic and hydrologic conditions;

3. fact sheets on specific farmstead structures or activities that include procedures to determine relative groundwater pollution potential based on current design, location, and management;

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4. procedures to integrate the site pollution vulnerability evaluation with the evaluation of groundwater pollution risk posed by each farmstead activity or structure, and a procedure to rank priority actions for minimizing groundwater pollution potential;

5. assessment delivery mechanisms (e.g., trained staff for delivery of materials and assistance to farmers in conducting assessments).

Process

1. Evaluate the site using a resource inventory and farmstead diagram. The first step in the farmstead potential assessment would be to compile existing site information from soil surveys, geological studies, and well construction reports. Farmers would complete the site evaluation by diagramming all the farm buildings and the location of farmstead activities in relation to the drinking water well location. Procedures would be included to assist the farmer/technical assistant in determining direction of groundwater flow, and suggestions provided for local sources of assistance such as the state or federal Geolcgical Survey.

2. Evaluate farmstead activities and structures using fact sheets. Farmers would then use a series of fact sheets to obtain information on pollution risks and existing state regulatory requirements associated with specific farmstead structures and activities, and potential health effects of pollutants. The fact sheets would address the following topics:

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a. Well design and location,

b. Pesticide handling, storage and disposal practices,

c. Fertilizer handling and storage,

d. Livestock waste storage facilities and practices,

e. Barnyard and feedlot design, location and management,

f. Silage storage facilities and practices,

g. Petroleum product storage and disposal practices,

h. Household wastewater treatment system location and management,

i. Farm and household hazardous waste disposal and recycling,

j. Milkhouse waste handling.

3. Determine priority actions to minimize potential for groundwater pollution. Next, the farmstead assessment procedure would assist farmers in integrating the groundwater pollution potential evaluation for each farmstead structure or activity (Step 2), with the site pollution vulnerability evaluation (Step 1). The result of this final step would be an assessment of relative pollution risks associated with different farmstead activities and structures, and a priority ranking of management changes and other actions needed to minimize the potential for groundwater contamination.

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Prototype

A prototype farmstead assessment procedure guided by the above principles is being developed by specialists at the University of Wisconsin-Extension and Minnesota Extension Service; with support from the North Central Regional Center for Rural Development, Region V of the Environmental Protection Agency, EPA's Great Lakes National Program Office, and the Wisconsin Department of Natural Resources (Jones and Jackson, 1989). Project cooperators are developing fact sheets specific to Wisconsin and Minnesota, with references to appropriate state regulations such as those for septic tanks, animal waste management, and pesticide and fertilizer storage; in addition to minimum separation distances from drinking water wells to various farm structures and activities. Farmstead assessment draft publications and procedures will be piloted in Wisconsin and Minnesota, and refinements will be made based on that experience. It is the intent of project cooperators that the state specific references (e.g., regulatory requirements; soil, geologic and hydrologic conditions) could be easily modified, and that the fact sheets and assessment procedures could be adopted by other states.

Project cooperators have also identified a need to expand the assessment beyond the farmstead to include cropland pollution potential evaluations. Soil, geologic, and hydrologic evaluation criteria developed for the farmstead assessment prototype will provide the basis for evaluating pollution potential associated with cropland management practices. This potential cropland evaluation component, along with the farmstead assessment prototype, would result in a complete farm assessment procedure.

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Incentives and Constraints to Development of Farmstead Pollution Potential Assessments

There are a number of incentives for the development of a farm pollution potential assessment system. Perhaps most important among them is the concern of the farm community and the environmental community about the problems associated with drinking water pollution from agricultural activities. An Iowa farmer survey (Padgitt and Kaap, 1987) indicated that farmers are as concerned about water quality as they are about the farm economic crisis. A Wisconsin survey of farmer participants in a drinking water education program showed significant interest in conducting farm pollution potential assessments to determine the potential of their activities causing contamination of the water they drink (Environmental Resources Center, 1988). Conservation and environmental protection groups are very concerned about agricultural contamination of surface and groundwater. A majority of states have identified agricultural nonpoint source pollution as a significant problem (U.S. EPA, 1989). This high level of individual concern, the documentation of agricultural pollution problems, and the requirement for agencies to address problems of agricultural impacts on water quality are major incentives for development of a farmstead pollution potential assessment program.

However, there are two significant constraints to development and delivery of an effective farm assessment program. The first constraint stems from the lack of data with which to determine a clear cause and effect relationship between agricultural activities and groundwater

pollution under different site conditions. Although there is clear evidence that some practices and structures are causing pollution under some site conditions, the cause-effect interactions are generally not well understood, and proven procedures for evaluating pollution potential related to these interactions are not available. (It should be noted that this is more of a constraint to regulatory approaches, which require a solid data base for legal reasons, than to voluntary approaches which can be based on interpretations of the best available data).

Although a great deal more needs to be known, a number of basic principles are well understood and can be applied to evaluate relative pollution risks. For example, soil surveys provide information that can be applied in this process, but little organized, detailed information is available about geological and hydrologic site conditions. Well construction reports and geologic logs are potential sources of information and could possibly be used in conjunction with topographic maps and limited hydrogeologic information to determine the direction of groundwater flow. However, even these limited data must be organized into usable farm pollution assessment procedures. These procedures should then be field tested to determine their effectiveness, acceptability, and suitability for potential expansion into a state or national approach to dealing with agrichemical water pollution.

The second major constraint to the development of a farm assessment system is the lack of trained support staff to implement the system. Agricultural businesses and agencies that might become involved in the

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delivery of relevant information, such as crop consulting and soil testing services and county conservation departments, vary considerably in their availability and expertise across the country. These limitations must be considered when developing a program to address improving farm management to protect water quality. Staff within USDA agencies (i.e., SCS and Cooperative Extension) tend to be specialists or experts in specific areas. They have an in-depth knowledge of pollution potential related to specific activities, but generally lack training and background related to the full range of farm management activities that can affect groundwater quality; methods to assess pollution potential from those activities; and changes in management needed to reduce that pollution potential.

Incentives and Constraints to Farmer Use of Farmstead Pollution Potential Assessments

There are three major incentives for farmer use of a farm assessment system. The first incentive is that farmers can minimize health risks by assessing the risk of contaminating their drinking water supply and acting to prevent such contamination.

The second incentive is economic. There are costs that could be avoided by using the assessment and taking preventative actions. For example, homeowners' insurance normally does not cover replacement of a contaminated well. The preferred solution in case of well contamination by volatile organic compounds, for example, is to drill a new well or otherwise obtain an uncontaminated water supply, and this can be an

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expensive prospect. Complete groundwater cleanup is seldom possible, is always expensive, and is thus an incentive for preventive action.

Third, farmers would use the farm assessment process to identify potential sources of groundwater contamination and actions needed to minimize pollution. Such actions could reduce potential individual liability for cleanup or for contamination of neighbors' water sources. Pollution liability is an emerging issue in farming areas. For example, insurance underwriters are separating pollution liability from farm liability policies, thus providing farmers with the option of purchasing pollution insurance to cover potential lawsuits by others or to pay cleanup costs associated with accidents, chemical spills, underground storage tank leaks, etc. (Yohr, personal communication, February 22, 1989). In Illinois, several hundred farmers have purchased pollution policies for several hundred dollars of additional cost per year (Vance, personal communication, December 7, 1988).

There are also potential constraints to farmer use of a farmstead assessment system. Farmers might fear that by participating in an assessment that they will face costs and litigation associated with problems they identify and to which they might have contributed. Farmers might also be unwilling to participate because they are just not convinced that farmstead activities have the potential to contaminate groundwater.

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POLICY OPTIONS FOR IMPROVING FARMSTEAD MANAGEMENT TO MINIMIZE GROUNDWATER CONTAMINATION

Existing Policy and Regulatory Framework

Many aspects of farm management are affected by existing requirements and policies. Some directly apply to farm activities, while others contain exemptions for farm operations but should still be considered by good farm managers in order to minimize the risk of environmental contamination from their activities. Requirements and policies relevant to the concept of a farmstead pollution potential assessment are summarized below.

EPA Agricultural Chemicals in Groundwater Strategy

The Agricultural Chemicals in Groundwater Strategic Plan (U.S. EPA, December, 1987) says that EPA will use a three pronged approach to prevent pesticides from reaching unacceptable levels in groundwater: 1) EPA will take uniform action for pesticides posing widespread national concerns, and will establish generic requirements for certain pesticide application and disposal practices that pose groundwater threats independent of site specific conditions; 2) EPA will restrict the use of certain pesticides at the state or county level to protect groundwater, although to the extent feasible statewide or local measures will be requested by EPA; and 3) EPA will encourage a strong state role in local management of pesticide use. States will have the opportunity to develop pesticide management plans, based on local differences in groundwater use, value, and vulnerability. The plan may be basis for EPA's registration of pesticides in that state (U.S. EPA, December, 1987).

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The EPA strategy assumes existence of a procedure to identify differing degrees of pollution vulnerability. If state plans are to be tailored to different conditions, a procedure for providing site specific information to farmers must also be developed. The farmstead assessment system described in this report could provide such a procedure.

EPA Agricultural Chemicals in Groundwater Nutrient Strategy

Although the initial focus of the Agricultural Chemicals in Groundwater Strategic Plan is pesticides, EPA also intends to develop a fertilizer strategy at a later date (U.S. EPA, June 1987). Presumably the strategy will be similar to the pesticide management strategy in encouraging strong state and local management efforts.

Water Quality Act of 1987

These amendments to the Clean Water Act authorized financial assistance for nonpoint source pollution control assessment and management reports, program development, and demonstration projects (U.S. EPA, December, 1987). Farmstead pollution potential assessments could be a component of state implementation of nonpoint source management programs.

Resource Conservation and Recovery Act (RCRA) Requirements

RCRA and parallel state laws were enacted to prevent careless handling and disposal of hazardous waste. All generators of nonhousehold hazardous

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waste have to comply with some regulations, which vary depending on the amount of waste generated (Wachs and Hamel, 1987). With the types and amounts of materials stored on farms, many farmers could be classified as "small quantity generators" of hazardous waste, and be subject to regulations.

Under federal and state regulations, small quantity generators must obtain an EPA identification number, comply with the requirements for on site accumulation of hazardous wastes, properly treat, store, dispose of or recycle those wastes at a hazardous waste facility; comply with hazardous waste transportation requirements; track all hazardous waste shipments; and report annually to state environmental agencies. Farmers who are classified as very small quantity generators of hazardous wastes (accumulate less than 2.2 pounds per month of acutely hazardous waste, or generate less than 100 kilograms and never accumulates more than 1000 kilograms on site) are not required to track their wastes, but are still responsible for disposing of such amounts in a hazardous waste facility or licensed solid waste facility (Wachs and Hamel, 1987).

Farmers who triple rinse empty pesticide containers can legally dispose of them in landfills or at a scrap dealer. However, some landfills will not accept the containers, or will require written certification that containers have been rinsed. For bags and boxes which have held pesticides and fertilizers, there are no required methods of disposal. These containers are often burned at the farmstead.

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Requirements for underground storage tank standards, financial responsibility, and recordkeeping are also covered in RCRA regulations. Federal regulations for underground storage tanks, effective in December of 1988, do not apply to farm use of petroleum products if farmers store less than 1100 gallons (Federal Register, September 23, 1988). Farmers in some states will still be subject to state reporting requirements.

SARA/Community Right to Know

Some farmers may have to report storage of certain pesticides under the community right-to-know provisions of the Superfund Amendments and Reauthorization Act (SARA) of 1986. If a spill occurs and chemicals have not been reported, a farmer would be subject to civil suits by the U.S. EPA. State agencies may also have spill requirements that farmers would have to follow (Flashinski, 1989).

Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)

FIFRA authorizes the Environmental Protection Agency to regulate marketing, use, and disposal of pesticides and their containers in the United States. Many states have similar authority under delegated programs, and are authorized to take enforcement actions against individual applicators of general or restricted use pesticides in violation of label requirements.

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1985 and 1990 Farm Bills

The 1985 Food Security Act reflects major changes occurring in agriculture by incorporating resource conservation provisions into commodity programs. The Act established penalties (loss of commodity program benefits) for cultivating highly erodible land after 1990 without an approved conservation plan, and for bringing into new production highly erodible lands or wetlands. The Act also established the Conservation Reserve Program to pay landowners to take highly erodible lands out of production for 10 years, and established a Conservation Easement Program. Expectations are that the 1990 farm bill will expand the link between conservation and commodity production by incorporating surface water and groundwater quality concerns (Leahy, 1988). Debate will likely focus on how to incorporate those concerns. National and state surveys have shown that farmers are concerned about groundwater quality and favor such actions as limits on pesticide use and expansion of the Conservation Reserve Program to protect groundwater (Wisconsin State Journal, Dec. 4, 1988).

Conclusions

Given the extent and complexity of the existing policy framework described above, it is understandable why some farmers may be unaware of regulations affecting their activities, or choose not to comply. A farm assessment system would be one means of communicating the above requirements or management considerations to farmers in an integrated

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fashion. Such an educational process would support implementation of these programs at the farm level, and encourage improved management to minimize the potential for groundwater contamination.

Options for Implementing a Farmstead Pollution Potential Assessment

Overview

This section identifies five potential program options for assisting farmers in conducting farm specific pollution assessments, and implementing management practices to reduce pollution potential. Policy implications and potential funding mechanisms for these options are also discussed. Under any option, development of the program would require:

a. Assembling and analyzing site pollution evaluation criteria;
b. Providing trained staff to assist farmers in conducting pollution assessments of their farms;
c. Developing support systems that facilitate the improvement of management in ways that reduce pollution; and
d. Organizing available soils, geologic and hydrologic data so that it is understandable and usable by farmers, or by consultants and agency staff who are assisting farmers in conducting the farm pollution potential assessment.

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A prototype farmstead assessment system is currently being developed (Jones and Jackson, 1989), and has been described in an earlier section of this report. This prototype could be modified for other resource and institutional situations, and could be expanded to result in a full farm assessment.

In the policy options discussed below, the Cooperative Extension Service, Soil Conservation Service, Soil and Water Conservation District staff, agrichemical industry representatives, and district/regional/state agency staff are mentioned as potential providers of technical assistance to farmers in conducting farmstead pollution potential assessments. Training of these potential assistants and oversight of their assistance to insure consistency would be essential. Technical assistants would, as appropriate, seek the expertise of local agricultural, natural resource, health, or environmental agencies. Understanding of the farmstead assessment system and support of the concept by those organizations would need to be cultivated.

Once a prototype farmstead assessment system has been developed, tested, and refined, it could be implemented in a variety of ways. For example:

1. Voluntary use by farmer; no assistance. Farmstead pollution potential assessment procedures would be available from local sources.

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2. Voluntary use by farmer; assistance provided to a group of farmers at one time. Local source would provide materials and organize group education meeting.

3. Voluntary use by farmer; assistance provided one-on-one. Local source would provide materials and assistance.

4. Required use by farmer, via cross compliance with commodity programs, or development of new regulatory program.

In short, the assessment system could range from the entirely voluntary to the entirely mandatory, with various levels of cost and personnel requirements.

The following discussion of policy options for implementing the farm assessment concept reflects the variety of possible approaches, and is not meant as a exhaustive list of possibilities.

Policy Options

1. Provide for voluntary site pollution potential assessments initiated by landowners. Farmer surveys in Iowa and Wisconsin indicate that farmers are concerned about the potential of pollution resulting from their activities (Padgitt and Kaap, 1987; and Environmental Resources Center, 1988). A second option for helping farmers evaluate and minimize pollution potential would be to establish a voluntary program to assist

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interested farmers. The program would have a number of characteristics similar to the home energy audit program.

The basic principles behind the home energy audit were that energy conservation was in clear interest of the homeowner, that a voluntary education and technical assistance program would therefore be effective, and that society as a whole would benefit from individual actions to conserve energy. The basic principle behind the voluntary farm pollution potential assessment is similar. Health concerns, liability concerns and potential pollution clean-up costs all provide significant incentives to reduce pollution potential. A voluntary program might therefore be effective, and society as a whole would share the benefits of improved water quality.

The Cooperative Extension Service (CES), the Soil Conservation Service (SCS), and the Soil and Water Conservation Districts (SWCD) could cooperatively develop and deliver the program, drawing on the data and expertise of other local health, agricultural, environmental, and natural resource agencies. CES, SCS, and SWCD are key agencies because their field staff are available in most counties. CES could offer drinking water education programs to explain the results of farm well water analysis. The explanation of the water analysis would be accompanied by information on groundwater recharge and movement, pollution movement, and how land uses influence the poten ial for contamination to occur. Individuals participating in this program would be offered the opportunity

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to conduct a farm pollution potential assessment of their farm. Options for conducting the assessment include: (1) a group education process in which farmers conduct their own assessments with CES, SCS, and SWCD staff assistance in interpreting and applying assessment criteria; (2) one-on-one farm visits in which trained staff collect information from the farmer and assist in applying and interpreting the data; or (3) printed guidelines to help farmers conduct their own assessments.

Group planning has been successfully used to develop farm erosion control plans. Those who have developed plans through this approach have implemented significantly higher proportions of their plans than those who have had their erosion control plans developed for them (Schaller, personal communication, December 14, 1988). Drinking water education programs have been an effective way of increasing farmer understanding of how land uses and management practices can cause contamination of well water and surface water. In one case more than seventy percent of nearly 220 farmers who participated in a CES sponsored drinking water education program indicated they wanted information that would assist them in conducting a farm pollution potential assessment. Forty-four percent indicated they would like on-farm, educational assistance in conducting an anonymous, farm pollution potential assessment (Environmental Resources Center, 1988).

As in the home energy audit program, private industries could be required to provide funding and or staff to implement this program. The

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energy audit program also offers assistance in making improvements that increase energy use efficiency. Home owners are offered advice on costs and contracting but pay for needed improvements. Offering similar assistance to farmers on practices that reduce pollution potential could significantly increase adoption of recommended improvements. Some practices will not require structural changes but require changes in management. Management improvements will require increased knowledge and understanding of appropriate procedures. Making these improvements would require new, focused education efforts.

2. Require agrichemical industry to provide pollution potential assessment assistance. In this option, farmers would conduct voluntary pollution potential assessments, but the agrichemicals industry would be required to provide assessment assistance. This option is modeled after the energy industry home energy audit in that it would rely on private industry to provide a service desired by landowners. Guidelines for conducting the assessment and staff training could be provided by educational institutions, or the CES. Support systems to facilitate the implementation of necessary management improvements could be jointly developed by the industry, universities, the CES and state and federal agencies with water quality or agricultural responsibilities.

Such a program would include benefits to industry. For example, any farm assessment program would include plans for on-farm pesticide mixing and loading, and handling and storage areas. The plans would be in an easily understandable format to promote their use. Farm assessment

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educational materials could be stocked by agrichemical distributors and used as promotional items. Crop consultants could conduct residual soil nitrate tests and calculate nitrogen credits from all available sources, and provide on-farm assistance to calibrate and retrofit pesticide application equipment.

Industry might also benefit from a program to facilitate the collection, recycling and or proper disposal of farm hazardous wastes. Agrichemical distribution points could also be agrichemical waste collection points.

The development of needed support systems will require a financial and staff commitment from all levels of government and the agrichemical industries.

3. Require that pesticide applicator training address pollution potential assessments. The EPA and states administer programs that provide for training and certification of pesticide applicators to ensure that restricted use pesticides, as classified by EPA, are used safely. As an expansion of these programs, EPA or states could require that farmers and commercial applicators applying pesticides in areas with a high groundwater pollution potential receive additional pesticide applicator training. This training would assist farmers in assessing the pollution potential of their agrichemical management practices around the farmstead and in their fields. Prior to receiving private applicator certification,

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the applicant could be required to complete an approved pollution vulnerability assessment and agrichemical management plans for their cropland and farmstead. Commercial applicators would learn the procedures for conducting pollution potential assessments, and could be required to conduct assessments on fields in areas vulnerable to groundwater contamination, prior to identifying a pest control strategy. On-farm mixing and loading areas and pesticide disposal practices pose a relatively high groundwater pollution risk regardless of site characteristics. These would be priority items in the farmer's agrichemical management plan.

Costs for this increased training could be covered through fees charged to participants, fees added to pesticide sales costs, state appropriations or federal appropriations. If the farm pollution potential evaluation addresses the full range of management around the farmstead and in the field, it would not be appropriate for the pesticide industry alone to cover the full costs of this program. Fertilizer and petroleum industries should also be considered as potential sources of revenue. There are precedents for such fees imposed on the agrichemical industry. For example Iowa uses pesticide dealer fees, pesticide registration fees and a nitrogen fertilizer tax to test wells, support sustainable agriculture and demonstrate agricultural management practices.

Development and implementation of this program would increase training time and costs for pesticide users and may increase costs of products if the chemical, fertilizer and or petroleum industries are required to

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provide funding to assist in program development and implementation.

4. Require farmstead assessment as part of Soil Conservation Service and Soil and Water Conservation District farm conservation plans. As described in an earlier section, a farm conservation plan assesses a farm's soil resources, and identifies structures and management practices needed to reduce erosion to acceptable levels. In some cases, the plan makes recommendations for management of other resources such as wildlife habitat or woodlots. The plans do not typically include an assessment of the groundwater resource, potential contamination from farming practices or steps to minimize pollution potential.

Strategies for environmentally sound use of fertilizers and pesticides might be viewed as a logical extension of the farm conservation planning process. However, because agrichemical management decisions are influenced by constantly changing economic, social, environmental and political (governmental) factors, it would be difficult for a one-time conservation plan to recommend specific cropland management strategies. A plan might more easily incorporate an assessment of farmstead groundwater pollution potential and recommend structures and practices needed to minimize pollution potential. The principle benefit of conducting a farmstead assessment as part of the farm planning process is that this planning is already familiar to farmers and has been expanded by the 1985 farm bill to cover many more farms than in previous years.

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Incorporating the farmstead assessment into the farm planning process would require considerable funding to SCS, SWCD and Cooperative Extension to train staff to conduct the assessment and to meet additional educational needs.

5. Develop a national nonpoint regulatory program. The effectiveness of a national nonpoint regulatory program would be limited by the variability of climatic factors, cropping systems and soil, geologic and hydrologic site conditions. Broad policies and guidelines can be developed nationally, but effective programs must take site-specific and crop-specific factors into consideration. A national program could be developed that would require the development and implementation of farmstead and field pollution potential assessments and management plans to reduce pollution potential in areas with high pollution risks, and in areas with high value water resources such as municipal water well recharge areas. Intensive monitoring and inspections in these high risk, high-value areas could result in an enforceable, effective program. Cost sharing and/or funds to purchase easements or provide other financial incentives to reduce the intensity of cropping practices might be necessary to meet pollution reduction goals. Considerable federal funding would be needed to develop and implement a federal regulatory program.

Conclusions

Developing a successful farm pollution potential assessment program will likely involve a combination of the above policy options. Before

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developing a full scale, national program, pilot educational materials and delivery approaches must be developed and field tested in areas that represent the wide range of agricultural diversity; and soil, geologic, hydrologic and climatic conditions under which the assessment system would need to function. When developing these pilot projects the relationship of specific program components to FIFRA, RCRA, CERCLA, Food Security Act (Farm Bill), and other relevant federally mandated programs must be considered. The pilot program could be funded by federal or state water quality management agencies and industry. The results of the pilot program would provide a clearer indication of roles, effectiveness of approaches, and staff and financial support necessary for state-specific modifications for particular resource and institutional conditions; enabling regional and national application of this concept.

The key to successful implementation of farmstead pollution potential assessments for minimizing groundwater contamination is farmer understanding of how their activities affect groundwater and in general their own drinking water quality in particular. That understanding should lead to a commitment to pollution prevention, and an alteration of attitudes and management practices where appropriate.

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APPENDICES

APPENDIX A	Tables
APPENDIX B	"Maintaining your Septic System." Wisconsin Department of Natural Resources, 1987.
APPENDIX C	"Groundwater and Environmental Pollution Self-Help Checklist for Farmsteads and Farm Fields." American Farm Bureau Federation, 1988.
APPENDIX D	Persons Cited as Information Sources and Their Areas of Expertise.

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TABLE 1: CONTAMINATION FROM PESTICIDE MIXING AND LOADING AREAS

	Maximum Concentrations Detected		
	In Pools and Soils in Loading and Rinse Areas	Groundwater in Affected Wells and Seeps	Local Background Groundwater
Herbicides	--- --- --- --- ---	ug/l --- --- --- --- ---	
atrazine	70,000	65.0	ND - 0.65
alachlor	270,000	145.0	ND - 1.30
cyanazine	225,000	36.0	ND - 0.26
metolachlor	270,000	50.0	ND - 0.80
metribuzin	52,000	8.0	ND
trifluralin	(1,000+)	0.2	ND
Insecticides			
carbofuran	(1,000+)	ND	ND
fonofos	(1,000+)	1.3	ND - 0.3
Fumigants			
EDB	(10	1.0	ND
1,2,dce	to	2.0	ND
Carbon Tet	100)	66.0	ND
Chloroform		4.0	<1.0
		--- mg/l	---
Nitrate (NO_3-N)		137-480 (30-105)	18-41 (4-9)

Pesticide and nitrate concentrations from 8 case studies where groundwater has been contaminated in the vicinity of farm-chemical supply dealerships (Hallberg, 1985).

TABLE 2: PESTICIDE RESIDUES AFTER RINSING CONTAINERS

Active ingredient in the 1 oz of liquid remaining in a 5-gallon container	
Rinsing stage	Pesticide residue
After draining	14.2 g
After 1st rinse	.2 g
After 2nd rinse	.003 g
After 3rd rinse	.00005 g

Source: Doersch et al., 1988.

B-1 Late

PUBL-WR-165 87REV
July 1987

This file contains information on how to use and maintain your septic system. It also provides a convenient place for you to record vital information about your system. Keep this folder with other important documents about your home and property.

Maintaining Your Septic System

Wisconsin Department of Natural Resources
U.W. Extension
Department of Industry, Labor, and Human Relations

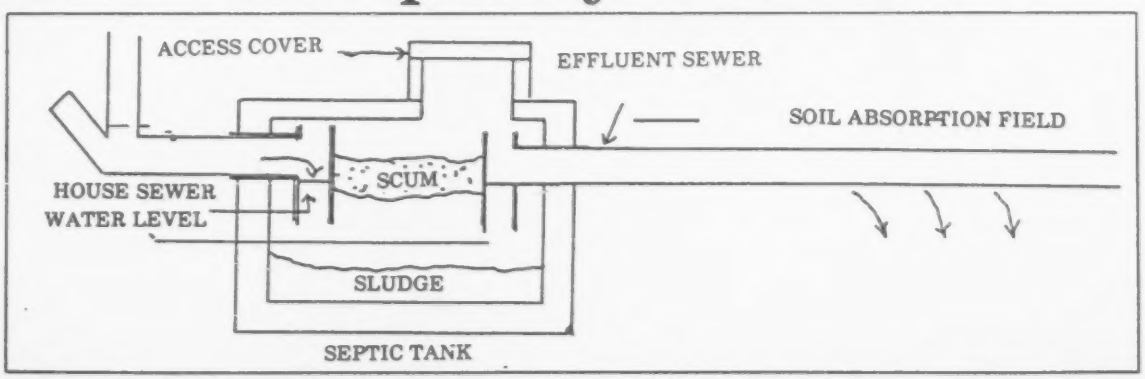
You would certainly never think of connecting the plumbing that carries wastewater from your house to the plumbing that carries fresh water to your drinking water tap. If you don't keep your septic system operating properly, that's exactly what you might be doing. An improperly sited, overloaded, improperly used and poorly functioning septic system can add nutrients bacteria and toxics to groundwater. Those pollutants can then be drawn into your well and come out the tap in your drinking, cooking and bathing water.

Even if you don't pollute your own or your neighbor's drinking water, improperly functioning septic systems can add pollutants to lakes and streams increasing weed and algae growth and in extreme cases killing fish. Repair or replacement of a failed system costs much more than regular maintenance.

All of this can be avoided if your septic system is:

- correctly sited
- properly designed
- carefully installed
- correctly used
- regularly maintained

How Your Septic System Works



Whatever you put into your toilets and sinks flows into the septic tank. In the tank, most solids settle to the bottom and are partially decomposed by bacteria to form sludge. Some solids float and form a scum on top of the water (see illustration).

The liquid in the tank — carrying bacteria, viruses, compounds of nitrogen and other potentially harmful substances — is discharged into a soil absorption field. The soil is your last line of defense to prevent polluted water from entering lakes, streams and groundwater. The wastewater is purified partially by the filtering action of the soil and the ability of microorganisms in the soil to decompose many of the remaining contaminants. The soil cannot remove dissolved contaminants (like nitrogen). The wastewater eventually percolates into the groundwater.

Septic System Maintenance

The Septic Tank

The tank is the part of the system requiring regular maintenance. You must have the tank cleaned out regularly so that sludge and scum don't build up. If you do not clean your tank when needed, sludge or scum will clog the outlet pipe or work their way out into the soil absorption field. This will clog the field and lead to early and costly failure of the whole system.

How do you know when your septic tank needs to be pumped? You can have a commercial pumper give you an idea of how often you should have the tank pumped. It depends on the size of your family, the volume of wastewater entering the tank, whether you use a garbage disposal and the capacity of the tank. Generally, for a family of four using a modern septic system, it's a good idea to have the tank pumped every two to three years (more often if you use a garbage disposal). If you don't want to pay to have the tank pumped at this interval, you can make your own determination about the need for pumping. You can do this by measuring the sludge depth in the tank. Here's how you do it:

1. Find the tank. Sometimes this is tricky. The tank's cover will usually be within a couple of feet below the ground surface but the depth can vary depending on how your land slopes. If you don't know where the tank is, you can probably find it by gently tapping a steel rod into the ground starting about ten feet from where the sewer drain leaves your house. If your tank has a observation pipe, the cover should be at the other end of the tank — a few feet toward the house. After you find the cover, you might want to mark it's location so you can find it again the next time.

2. Remove sod and soil until you can lift the cover.

3. Find a six to eight foot pole or thin board. Wrap the bottom three feet with white rags.

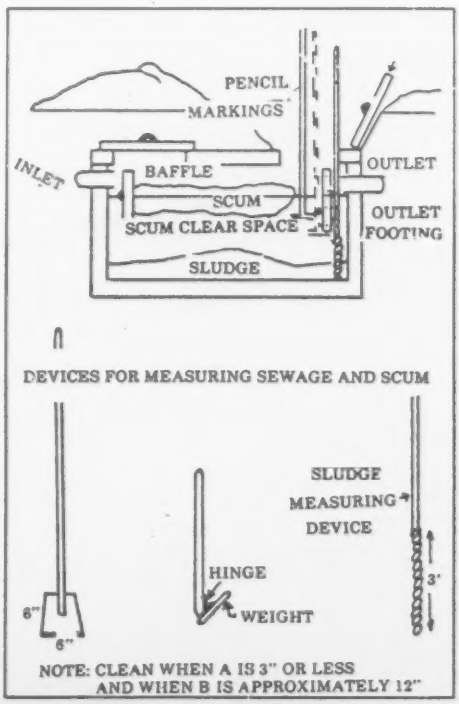
4. Lower the wrapped part of the stick through the sludge to the bottom of the tank. If possible, lower it between the outlet baffle and the outlet (see illustration).

5. Hold the stick there for several minutes, so that the sludge will get the rags good and black.

6. Remove the stick and note the sludge line and the liquid line. The sludge line will be darker than the coloration caused by the liquid waste.

7. If the sludge line is more than one-third of the liquid level, it's time to have the tank cleaned. For example, if the total length of your stick that is wet is 48 inches, the tank should be pumped if the dark sludge portion is over 16 inches.

The gases generated in a septic tank are dangerous, and can kill. Never enter a septic tank. Only trained persons with life support equipment should ever enter a septic tank.



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The Soil Filter

The area of ground where the septic tank liquid soaks into the ground is called the soil absorption field, drain field, seepage bed or dry well. It is a filter. If it is properly installed and used, it will filter septic tank discharge for many years. The soil absorption field should require no maintenance if a few simple precautions are followed.

1. Minimize your water use so that you do not overload the filter.
2. Be absolutely sure your septic tank is working properly. Never allow sludge or scum to escape from the tank.
3. Some systems are equipped with a pump or dosing chamber that floods the absorption field in controlled doses rather than letting effluent continuously trickle from the tank. Other systems include a lift station. Make sure that all pumps or siphons are operating properly. Your plumber can give you advice on how to check your particular system.
4. Avoid compacting the soil that acts as a filter for effluent leaving the tank. Keep cars and other heavy equipment off the absorption field.
5. Avoid overloading the absorption field by sloping the land above it so surface water does not pond on it. Make sure that downspouts from your house or other buildings carry water away from the field. Never pile winter snow on the field.
6. Mark the boundaries of your drainage field as a reminder. There may be one or more vent pipes to serve as guides.

Household Hints That Help

To minimize maintenance costs • To protect your lake • To prolong the life of your system

DO

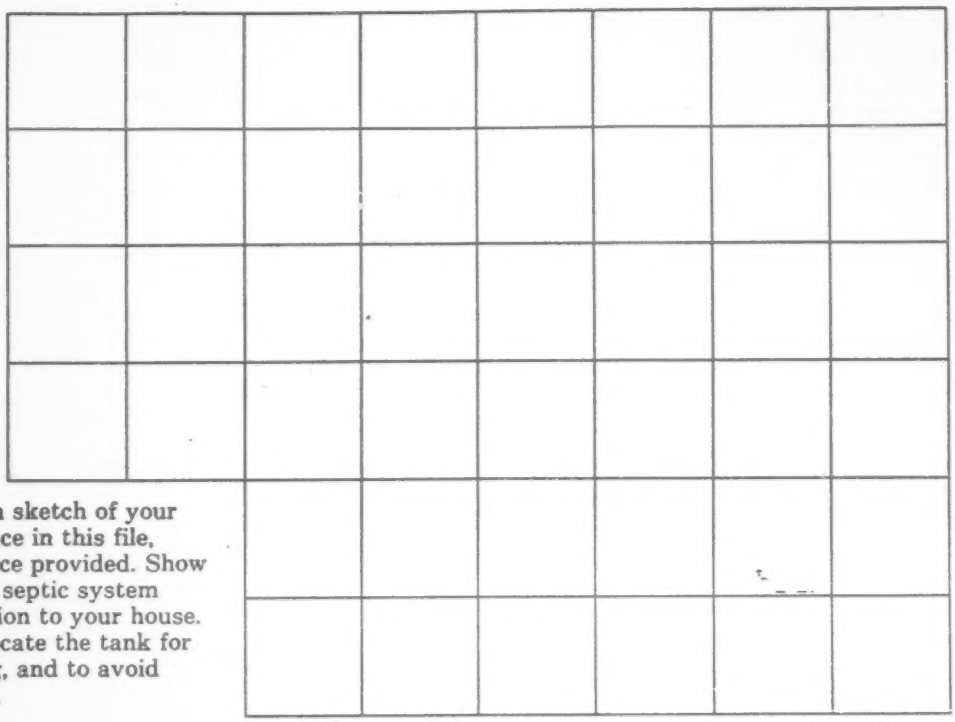
- Limit the water entering your tank. Use water saving fixtures. Fix toilet float valves, leaks and dripping faucets. Spread clothes washing over the entire week.
- Pump the tank when necessary. This means every two to three years (more often if you use a garbage disposal) or as indicated by your annual inspection.
- Divert surface water drainage away from the absorption field.
- If you are buying a house with a septic system, have the system evaluated. You may want to have the soil tested for compliance with the state uniform plumbing code.

DON'T

- Do not connect the basement sump pump to the septic tank.
- Do not put materials down drains that will clog the septic tank (fats, grease, coffee grounds, paper towels, sanitary napkins, disposable diapers, etc.).
- Do not put toxic substances in drains that might end up in the groundwater (cleaning fluids, oils, paints, disinfectants, pesticides, etc.).
- Do not use chemicals to clean or "sweeten" your system. They may interfere with the biological action in the tank, clog the drain field by flushing sludge and scum into the field or add toxic chemicals to groundwater.

B-

Septic System Layout



If you do not have a sketch of your septic system to place in this file, make one in the space provided. Show the location of your septic system components in relation to your house. Use the sketch to locate the tank for testing and cleaning, and to avoid damaging activities.

Maintenance Record

Keeping a record of your septic system maintenance activities will help you anticipate when the next cleaning is needed.

Information Directory

Plumber/Installer
Name _____
Address _____
Phone _____

Pumper
Name _____
Address _____
Phone _____

DILHR District Office
Name _____
Address _____
Phone _____

County Sanitarian (or Code Administrator)
Name _____
Address _____
Phone _____

DNR Lake Management Coordinator
Name _____
Address _____
Phone _____

Extension Agent
Name _____
Address _____
Phone _____

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Farm Bureau's
Groundwater & Environmental Pollution

Self-Help Checklist

for Farmsteads and Farm Fields

Purpose: This thought-provoking checklist will help you analyze your own water supply and farming operations.

- Fill out this Checklist
- Review it once a year, and
- Act voluntarily to reduce or prevent pollution from your farming activities.

IS YOUR DRINKING WATER SAFE?

I. BASIC INFO ON YOUR WATER SUPPLY & TESTING, CLIMATE AND SOILS:

Which system provides drinking water for your family and/or livestock?

___ **PUBLIC** (EPA defines it as any system with 15 or more connections or serving 25 or more people, including most rural water districts.) Water testing and treatment required by federal Safe Drinking Water Act.

___ **PRIVATE** (includes your own system; bottled water; and systems with 14 or fewer connections or systems serving 24 or less people). Water tests generally not required except for dairies and for new wells.

Check ✓ the source/s from which your system draws its water:

GROUNDWATER	SURFACE WATER
___ Shallow well, 0 to 50 ft.	___ Stream
___ Medium well, 50 to 150 ft.	___ River
___ Well deeper than 150 ft.	___ Farm pond
___ Artesian well	___ Lake
___ Spring	___ Cistern

___ Don't know, but I intend to find out.

Is your water treated to kill bacteria? ___ Yes ___ No

If you have a well, is it dug, drilled, or sandpoint? _____

In what year was your well constructed? _____

Is your well properly grouted to prevent contamination from rainfall and animal contamination from seeping down along the well's casing? ___ Yes ___ No ___ Don't Know

Does your well's casing extend above ground level? (It should.)
___ Yes ___ No

WATER TESTING

Have you had your water tested within the last year?
___Yes ___ No
If No, what year did you last test it? _____

Did the test include any of the following? Check those that apply.

___ pH
___ Nitrate
___ Total Coliform Bacteria
___ Total Dissolved Solids

Done by many state health labs for a small fee. Should be done annually even if no obvious problems exist.

___ Pesticide Scan
___ Heavy Metals (lead, arsenic, etc.)
___ Purgable Organic Carbons (fuels, dry cleaning solvents, etc.)

CLIMATE and SOILS

What is the average rainfall for your area? _____ inches.
(Leaching potential increases as annual rainfall increases.)

Is the bedrock limestone? (Karst Topography) ___ Yes ___ No

Are your topsoils shallow to bedrock (less than 3 ft.)
___ Yes ___ No
(Thicker top soils may still be a problem depending on soil type.)

Are your soils generally:
___ Sandy (most likely to allow leaching into groundwater)
___ Loams (medium leaching potential)
___ Clays (least likely to allow leaching)
___ High organic matter (peat or muck)
___ Loam or some combination of those listed above?

How are any ponds or impoundments on your farm recharged?
___ rainfall/runoff
___ groundwater/spring
___ stream
___ pumped well

2nd Edition, January 1988

II. CHECK YOUR FARM'S POTENTIAL TO POLLUTE GROUNDWATER AND YOUR DRINKING WATER SUPPLY

DO YOU:	YES*	NO
• Have limestone bedrock fairly close to the surface? *(Cracks and sinkholes provide fast movement of runoff and pollutants to groundwater and wells many miles away.)*	___	___
• Have sandy soils? *(Fertilizers and chemicals can move rapidly to groundwater.)*	___	___
• Have water tables within 30 ft. of the surface?	___	___
• Have a dug or sandpoint well less than 50 ft. deep? *(These are generally old, not properly cased or grouted. Easily contaminated by bacteria, rodents and surface runoff.)*	___	___
• Have a well pit, uncapped well or abandoned well? *(Easily contaminated by surface runoff, flooding and rodents.)*	___	___
• Have an older submersible well pump? *(Many older pumps contain lubricating oil with highly toxic PCBs which could contaminate your water supply system.)*	___	___
• Have lead water pipes or lead-soldered pipe joints? *(Lead is highly poisonous and could leach into drinking water, especially if the water is acidic.)*	___	___
• Use your well for both livestock & household use? *(Potential for cross contamination exists.)*	___	___
• Have livestock/poultry within 200 ft. of a well? *(Bacteria, nitrates and disease may reach the well water.)*	___	___
• Have a feedlot, manure lagoon or holding facility?	___	___
• Have a septic tank/field within 75 ft. of a well (double the distance in sandy soil)? *(Bacteria and nitrate contamination is possible.)*	___	___
• Have a surface water drainage well? *(Runoff moves chemicals & manure directly into groundwater.)*	___	___
• Have a farm dump? *(Improperly disposed house & farm chemicals and animals.)*	___	___

DO YOU:	YES*	NO
• Have an underground fuel tank? *(Average life of steel tanks is 40 years or less.)*	___	___
• Put chemicals or fertilizers into your irrigation system? *(Without proper checkvalves and equipment the potential for backflows into the well exists if the system malfunctions.)*	___	___
• Use chemicals from EPA's Priority Leachers List (see list below)? *(If you do use them, try to find a substitute chemical which is equally effective but less likely to leach to groundwater.)*	___	___
• Apply sewage sludge? *(Possible problems with heavy metal buildup, disease and nitrates if not monitored carefully.)*	___	___
• Dump or spread used oil to control road dust? *(EPA considers this hazardous waste, better recycle it.)*	___	___

IF YOU CHECKED "YES" FOR ONE OR MORE OF THE QUESTIONS ON PAGE 3 AND 4 YOU SHOULD DEFINITELY BEGIN A PROGRAM OF ANNUAL WELL WATER TESTING!

*Also, if you checked the "YES" column you should try to reduce your system's pollution potential and/or reduce your production costs.

EPA PRIORITY LEACHERS *(Current as of October 21, 1987 but could change)*

acifluorfen
alachlor
aldicarb
aldicarb sulfone
aldicarb sulfoxide
ametryn
atrazine
atrazine, dealkylated
baygon
bromacil
butylate
carbaryl
carbofuran
carbofuran-3OH
carboxin
carboxin sulfoxide
chloramben
alpha-chlordane
gamma-chlordane
chlorothalonil
cyanazine
cycloate
2,4-D
dalapon
dibromochloropropane
DCPA
DCPA acid metabolites
diazinon
dicamba
5-hydroxy dicamba
3,5-dichlorobenzoic acid
1,2 dichloropropane
dieldrin
diphenamid
dinoseb
disulfoton
disulfoton sulfone
diuron
endrin
ethylene dibromide
ETU
fenamiphos sulfone
fenamiphos sulfoxide
fluormeturon
heptachlor
heptachlor epoxide
hexachlorobenzene
hexazinone
methomyl
methoxychlor
methyl paraoxon
metolachlor
metribuzin DA
metribuzin DADK
metribuzin DK
nitrates
oxamyl
pentachlorophenol
pichloram
pronamide metabolite, RH 24,580
propachlor
propazine
propham
simazine
2,4,5-T
2,4,5-TP
tebuthiuron
terbacil

III. OFF-SITE ASSESSMENT

(i.e., are other people's actions affecting your water supply?)

What is the approximate distance to the nearest neighbor's well? (Express in feet or miles) _____.

Is that well: ____ shallow (less than 50 feet); ____ deeper than 50 ft.?

From a map or by observation, in what direction does the groundwater flow through your property? From the _____

_____ to the _____. (Check with local Soil Conservation Service or State Geological Survey if you don't know the answer.) Often times groundwater moves toward the nearest creek or river.

Place a check mark ✓ next to all **POLLUTANT SOURCES** within a 1-mile radius of your property where the groundwater seems to be coming from. (If your farm's water supply is surface water you may have to think in terms of many miles upstream.)

Pollutant Source	Potential Pollution or Problem	If You Suspect/ observe these Problems, Request These Tests
____ Ag Areas	All problems listed in Part II	TC, NO_3, pH, TDS, Pesticide Scan.
____ Wetlands	Polluted recharge water.	Bacteria, NO_3.
____ Forests	Pesticide use.	Pesticide scan.
____ Highways	Road salt, lead petroleum.	TDS, chlorides, sodium.
____ Housing	Septic, house and lawn chemicals.	NO_3, surfactants, Fecal Coliform & Streptococcus.
____ Fuel Tank	Gasoline, diesel.	Hydrocarbon scan.
____ City	Street runoff, fuels.	TDS, pH, Hydrocarbon scan.

(Continued)

Pollutant Source	Potential Pollution or Problem	If You Suspect/ observe these Problems, Request These Tests
____ Industry	Metals, fuels, solvents, acids.	TDS, pH, Hydrocarbon scan.
____ Food Ind.	Rinse water, cleaning solvents.	Bacteria, TDS, pH, Surfactants.
____ Injection Well	Brine, chemicals, & acids.	TDS, pH, acidity, Hydrocarbon Scan, Corrosion Index.
____ Mining	Acid, salts, minerals.	TDS, Fe, SO_4, pH, Mn, Al, acidity Corrosion Index.
____ Oil & Gas	Brine, sulfur & minerals	TDS, Na, Cl, Ba, Pb, pH, Strontium, Corrosion Index.
____ Golf Club	Pesticide and Fertilizer use.	NO_3, pH, Pesticide Scan.
____ Landfills	Chemicals of all sorts.	TDS, pH, COD, Volatile organics.
____ Sludge	Heavy metals, bacteria.	Bacteria, nitrate, metals.
____ Utilities	Seepage from storage ponds.	TDS, pH
____ Other		

TDS = Total Dissolved Solids, TC = Total Coliform Bacteria, NO_3 = Nitrates, Al = Aluminum, Fe = Iron, Cl = Chlorides, Mn = Manganese, Ba = Barium, SO_4 = Sulfates, COD = Chemical Oxygen Demand, Pb = Lead, Na = Sodium.

If there is any question in your mind about how any of the pollutant sources you checked above may be affecting your water supply then you should have your water tested. This gives you a baseline against which to compare water test results in future years.

Work closely with local government to deal with off-farm problems.

IV. FERTILIZER CHECKLIST

DO YOU:	Yes	No	Can Improve* Investigate	Does Not Apply
• Soil test every year, including 2 to 3 feet deep? ... *(Deep testing is important in drier climates to determine how much of last year's nitrogen fertilizer remains within the plant's reach.)*	___	___	___	___
• Have a nutrient "BUDGET" for your cropland? ...	___	___	___	___
• Split nitrogen applications by plant growth stages? ...	___	___	___	___
• Give fertilizer credits to manure or sewage sludge? ...	___	___	___	___
• Give nitrogen credits for previous crops such as alfalfa, soybeans, clover, vetch and other legumes? ..	___	___	___	___
• Band fertilizers where possible? .. *(Banding reduces the amount of rainfall that contacts the fertilizer as the rainfall percolates down through the soil. Banding also reduces the chances of weeds using the fertilizer before your crop does.)*	___	___	___	___
• Use goggles and rubber gloves around anhydrous ammonia?	___	___	___	___
• Reduce use of nitrogen fertilizers in the fall? ... *(Spring use increases yield and reduces NO_3 leaching.)*	___	___	___	___
• Use N-inhibitors, such as N-Serve? ...	___	___	___	___
• Set "Realistic" yield goals? ... *(10 percent higher than the average yield for the last 3 years is reasonable.)*	___	___	___	___

*Even if you checked the YES or the NO column you also should check

V. STORAGE OF AG CHEMICALS

DO YOU:	Yes	No	Can Improve* Investigate	Does Not Apply
• Know whether your fire department would let a building burn if it contained ag chemicals, rather than risk having their water carry chemicals to groundwater or nearby streams? ...	___	___	___	___
• Padlock chemical storage areas? ..	___	___	___	___
• Keep duplicate records of amounts and types of chemicals in storage and keep one set someplace else other then your chemical storage building? ... *(The extra record is useful in case of fire.)*	___	___	___	___
• Know which chemicals must be stored in a heated area to prevent loss of effectiveness due to freezing? ...	___	___	___	___
• Have any chemical containers with missing or unreadable labels?	___	___	___	___

VI. HANDLING & APPLICATION OF AG CHEMICALS

DO YOU:

• Know that different parts of your body absorb pesticides at different rates? ...	___	___	___	___

Anatomy	% Parathion Absorption
scalp	32.1
ear canal	46.5
forehead	36.3
forearm	8.6
palm	11.8
abdomen	18.4
scrotum	100.0
ball of foot	12.6

(Researchers in California measured the percent absorption of parathion by different parts of the anatomy:) Most other pesticides have not been checked for body absorption rate.

DO YOU:	Yes	No	Can improve* Investigate	Does Not Apply
• Know that symptoms of low-level organophosphate insecticide poisoning closely mimic the symptoms of exhaustion or flu? ..... *(Symptons include headaches, loss of appetite, nausea, dizziness, weakness and sweating.)*	___	___	___	___
• Know that a product with higher water solubility, longer persistence, and low soil absorption has a greater potential of reaching groundwater?	___	___	___	___
• Use Integrated Pest Management (IPM) to determine whether the $ loss to the pest is great enough to warrant spraying, rather than spraying by schedule?	___	___	___	___
• Use one of the five specifically defined types of conservation tillage (reduced till, mulch till, slot till, ridge till, or no-till? ..... *(They reduce the amount of soil, chemicals & fertilizer that is eroded to surface waters.)*	___	___	___	___
• Band herbicides, insecticides, and other chemicals, rather than broadcasting them, to cut your costs and reduce their potential for pollution?	___	___	___	___
• Read the label before applying any chemical, and follow it?	___	___	___	___
• Calibrate spray nozzles before use? .	___	___	___	___
• Know about electrostatic sprayers? *(Greater % of spray stays on crop.)*	___	___	___	___

DO YOU:	Yes	No	Can improve* Investigate	Does Not Apply
• Mix and load chemicals and fertilizers at least 100 feet away from your well? ..... *(The closer you are, the easier it is for spilled chemicals to get into well.)*	___	___	___	___
• Use rubber gloves and boots when handling chemicals? ..... *Leather absorbs chemicals and keeps it in contact with your skin for days.)*	___	___	___	___
• Measure concentrates and dilutions accurately before adding to tank?	___	___	___	___
• Drain the container into the spray tank by holding it in the vertical position for 30 seconds?	___	___	___	___
• Triple rinse containers as soon as they are emptied before the residue dries?	___	___	___	___
• Empty rinsate into your spray tank?	___	___	___	___
• Have an air gap between the water supply hose and the top of your spray tank to prevent back-siphoning?	___	___	___	___
• Have check valve and proper safety equipment on irrigation wells?	___	___	___	___
• Pump tailwater pits often and reuse the water for irrigation to prevent chemical residue from leaching into groundwater?	___	___	___	___
• Use irrigation scheduling? ..... *(If soil is at field capacity, excess water and chemicals will likely move down past root zone.)*	___	___	___	___

*Even if you checked the YES or the No column you also should check the "Can Improve" if you think there's the slightest chance you could reduce your system's pollution potential and/or your production costs.

DO YOU:	Yes	No	Can Improve* Investigate	Does Not Apply
• Delay application to prevent wash-off or surface runoff if heavy rain is forecast?				
• Drive tractor into wind or at right angles to the wind whenever possible when spraying to prevent drift from getting on you?				
• Refrain from draining rinse water from equipment near or into ditches, streams, ponds, lakes or other water sources? *(Rinse waters containing any quantity of certain pesticides are classified as hazardous wastes according to state and federal laws.)*				
• Wear one of the new types of disposable coveralls when mixing or applying chemicals? *(It's not very expensive and they do a good job of protecting you.)*				
• Use Extension Service recommendations for washing spray clothes?				
• Use crop rotation to avoid buildup of pest populations and maintain or improve soil conditions?				
• Alternate pest control products and use crop varieties that are pest resistant?				
• Have general groundwater pollution liability insurance?				
• KEEP COMPLETE APPLICATION RECORDS? *i.e. which chemical, how much, application rate, date, time, temperature, wind conditions, which field, and reason for spraying.)*				

VII. CONTAINER DISPOSAL

DO YOU:	Yes	No	Can Improve* Investigate	Does Not Apply
• Return unopened chemicals for a refund?				
• Check the product label for specific container disposal instructions from the manufacturer?				
• Triple rinse and puncture metal pesticide containers and recycle or dispose of them in approved landfills?				
• Follow local and state laws on disposal of plastic and paper pesticide containers?				
• Live in an area that sponsors voluntary container collection programs? *(If not, you might want to help start one.)*				
• Burn plastic, paper, and other combustible materials after each day's use per application site?				
• Burn only in daylight hours and have one person responsible to be in attendance for the entire period of the burn?				
• Dispose of used motor oil at recycling centers?				

*Even if you checked the YES or the NO column you also should check

VIII. HOW TO TAKE A WATER SAMPLE

Always contact the lab where you plan to have the water tested, and ask them for sampling methods, containers, and packaging and delivery instructions.

Your method and timing of taking a sample will vary slightly depending on which point in the system you are concerned about:

1. Actual quality of the main source of water, (groundwater, stream, river, or main distribution lines of a public water system), remove the faucet's aerator, sterilize the faucet opening by flaming and let the water run for 10 minutes before taking the sample.
2. Condition of your water pipes or storage tanks. Remove the aerator from your faucet, sterilize the faucet opening with flame, and take the sample within 3 or 4 seconds after you turn the water on.

TYPE OF SAMPLING CONTAINER. For some tests, water samples can be submitted in a plastic bag or bottle. Other tests require special dark-colored glass bottles. ASK THE LAB!

TIMELINESS. Usually, it's best to test the sample as soon as possible. Labs should receive samples within 24 hours (48 hours at the latest).

HANDLING OF SAMPLE CONTAINERS.

- Do not touch the inside of the container or inside of the lid.
- Refrigerate or pack in ice and deliver to lab as quickly as possible if lab so instructs. (Don't throw the sample in the back seat and run all your errands before you stop at the lab.)
- Don't pump gasoline before taking the sample: ethylene dibromide (EDB) in the gasoline will evaporate off your hands into the sample.

For most accurate results, water samples should always be collected by a disinterested third party trained in proper sample collection procedures, and samples should be tested at an Environmental Protection Agency certified laboratory.

IX. RECOMMENDED INDIVIDUAL ACTIONS

1. Even if no obvious water problems exist, **household water supplies should be tested ANNUALLY** by your county or state Health Department for: pH, nitrates, total coliform bacteria, and total dissolved solids.

   Testing water for every contaminant is possible, but very expensive and not necessary. **It is more important to test on a regular basis for a few indicators of contamination and to maintain a record of water quality.** This helps to identify changes in the supply, contamination of the water source or deterioration of the water system. However, if you suspect other contaminants, test for them too.

2. Test livestock and poultry water supplies ANNUALLY for pH, total dissolved solids, sulfate, flouride, calcium, magnesium, iron, copper, arsenic, cadmium, lead, nitrate, barium, total coliform, fecal coliform bacteria, and total plate count.

3. Review this Checklist at the end of each calendar year and jot down which potential problem areas you improved on, and which ones you can work on in the coming year.

Record of Household Water Tests

Year	Date	pH 6.8 to 7.5*	Nitrates NO_3-N 10ppm*	Total Coliform Bacteria 0/100ml*	Total Dissolved Solids 500ppm*	Other
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
1996						
1997						
1998						
1999						
2000						

ppm = parts per million ml = milliliters
*ACCEPTABLE LIMITS WITHOUT TREATMENT

BEST AVAILABLE COPY

X. SUGGESTED LOCAL FARM BUREAU ACTIVITIES

- Help see that as many farmers as possible get to use this checklist at various meetings. At these meetings, always try to bring in a local water quality expert to make a presentation and answer questions.
- As an educational service, set up a booth at a county fair or a farm show or field day and test water samples for nitrates. (Pennsylvania Farmers Association (PFA) tested over 1,000 samples that farmers brought into PFA's booth at Ag Progress Days. Cost was only 20 cents/test.)
- Hold a county-wide Safe Drinking Water Clinic in cooperation with Extension Service, county Health Department, local well driller, and local water conditioning and testing companies. Pennsylvania Extension Service has an excellent model for this activity. (Your state Farm Bureau NER Coordinator can get more information about it from AFBF.)

If you have questions or want more information, call your:

- County Extension Agent
- Soil Conservation Service
- Local Water Testing Lab
- Regional U.S. EPA Office
- State Dept. of Agriculture
- State Health Dept.
- State Environmental Agency

FOR FURTHER READING:

Contact your state or county Farm Bureau office and request the publication: "Protecting our Groundwater, a Grower's Guide".

BACKGROUND: This checklist was developed as a result of a recommendation by the American Farm Bureau Federation's Special Study Committee on Environmental Pollution.

The committee report stated:

> Physical conditions affecting the vulnerability of groundwater to agricultural chemical contamination involve depth to the water table, recharge characteristics, aquifer media, soil types, topography, impact of unsaturated zone, and the conductivity of the unsaturated zone. All these discussions pointed to the "site specific" nature of the resource considerations...
>
> Information on farm management practices that will reduce the potential for movement of agricultural chemicals downward into the groundwater is needed at the user level... There is also a need to promote increased understanding of practices that will improve nutrient management and minimize nitrogen losses to the environment.
>
> As part of the effort required to educate farmers on the safe, responsible practices in agricultural chemical use and environmental concerns, there could be made available through states an Environmental Audit Program for self-examination by individual farmers.
>
> The questionnaire/checklist type program would be designed to highlight the basic safe environmental checkpoints on the farm, for example safe storage and handling of agricultural chemicals, mixing and loading locations and techniques.

The Committee recommended that the self-help program be developed by AFBF "for dissemination to State Farm Bureaus for use at the County level by individual farmers."

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APPENDIX D

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AGRICULTURAL BEST MANAGEMENT PRACTICES: IMPLICATIONS FOR GROUNDWATER PROTECTION

by

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March 1989

This contractor document was prepared for the Office of Technology Assessment (OTA) assessment entitled Beneath the Bottom Line: Agricultural Approaches to Reduce Agrichemical Contamination of Groundwater. It is being made available because they contain useful information beyond that used in the OTA report. However, they are not endorsed by OTA, nor have they been reviewed by the Technology Assessment Board. References to them should cite the contractor, not OTA, as the author; a suggested citation format follows:

Author(s) name(s), Contract paper title, prepared for the U.S. Congress, Office of Technology Assessment, *Beneath the Bottom Line: Agricultural Approaches To Reduce Agrichemical Contamination of Groundwater* OTA-F-418 (Washington DC: U.S. Government Printing Office, November 1990).

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ABSTRACT

This report examines the present use of Best Management Practices (BMPs) for control of nonpoint source (NPS) pollution from agriculture, and their effectiveness for control of agricultural groundwater contamination. Alternative approaches to groundwater protection from agricultural activities are also discussed. The concept of agricultural BMPs was developed as a voluntary approach to control of agricultural NPS pollution, primarily surface water contamination by sediment, nutrients, pesticides, BOD and coliform bacteria. The federal government has funded only a few BMP implementation programs beyond state planning grants and the Model Implementation Program (MIP) and Rural Clean Water Program (RCWP) research demonstration projects. Findings of these projects and others, such as the Black Creek Project in Indiana and the Honey Creek Project in Ohio, suggest that the present BMP approach is not likely to be effective in controlling either surface or ground water agricultural pollution unless project resources are strictly allocated to the more pollution-sensitive areas. Analysis of existing BMPs indicates that most were developed for erosion control and are also effective at controlling surface runoff of sediment-bound nutrients and pesticides. These practices will have little effect on groundwater quality, and in some cases, there may be tradeoffs between surface and ground water protection. Specific groundwater protection approaches which have the greatest potential include: expansion of FIFRA provisions to screen pesticides for groundwater leachability and to restrict pesticide use in sensitive groundwater areas; implementation of the Wellhead Protection Act for pesticides and nitrate; development of regulations to restrict nitrogen application rates from livestock waste in sensitive surface and ground water areas; end-of-pipe treatment of drinking water for private and small community wells.

INTRODUCTION

The last decade has seen a growing concern by the general public over contamination of the nation's groundwater. This concern stems from our growing dependence on groundwater and the increasing contamination of private and public wells. Groundwater represents 24 percent of the nation's domestic, agricultural and industrial water use, and groundwater withdrawals have increased 162 percent in the period 1950 to 1980 (EPA, 1984). Groundwater contamination is of concern because at least 50 percent of the U.S. population depends on groundwater for drinking. Almost all rural households depend on groundwater.

Until recently, the public's concern for groundwater contamination centered around bacteria and other pathogens which could be effectively treated with disinfection. Chemical contamination has increasingly been seen as a more pervasive and intractable problem. Industrial and municipal landfills/lagoons, underground storage tanks, chemical spills, well injection sites, septic tanks, pesticide and fertilizer use, concentrated livestock operations and other more minor sources are now known to be leaking chemicals into groundwater at concentrations that sometimes exceed drinking water standards or health advisories. More troublesome contaminants include: gasoline and its additives, organic solvents, trace elements including selenium, arsenic, boron and molybdenum, industrial organic and inorganic chemicals, pesticides, nitrate and pathogens.

Agriculture - primarily for irrigation - is the major user of groundwater in the United States. Agriculture also affects more of our land surface than any other activity. EPA has in the last 15 years begun to address water pollution associated with agricultural activities. The 1972 and 1977 amendments to the Clean Water Act (CWA) provided for nonpoint source (NPS) pollution abatement planning. The 1987 Act requires states to prepare NPS Assessment Reports which identify their NPS water pollution problems, and NPS Management Programs which detail how they are going to abate NPS pollution over the next four years. These

programs use voluntary approaches and implementation funds are limited relative to the needs (the 1987 CWA provides a variety of funding sources, i.e., Sec. 205(j)(5), Sec. 201(g)(1)(B), and Sec. 603(c)(2)). The 1985 Food Security Act mandates several environmental protection programs that deal only indirectly with surface and ground water.

This report deals specifically with the impact of U.S. agriculture on groundwater contamination and examines the potential for agricultural best management practices (BMPs) and other strategies to protect groundwater.

CURRENT BMP PROGRAMS

Definition of Agricultural BMPs

BMPs are defined as "... those methods, measures, or practices designed to prevent or reduce pollution. They include, but are not limited to, structural and nonstructural controls and operation and maintenance procedures. They are often used in varying combinations to prevent or control pollution from a given nonpoint source." (EPA, 1984).

Regulatory History

Agricultural pollution is regulated under several federal statutes: a) the 1972, 1977 and 1987 CWA amendments specifically address NPS pollution, a major contributor to which is agriculture in most states; EPA's NPS program is administered primarily through CWA; b) the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) gives EPA broad authority to register and otherwise regulate pesticide use in the United States; c) the Safe Drinking Water Act (SDWA) also empowers EPA to address agricultural NPS problems; e) the 1985 Food Security Act contains several conservation provisions (conservation reserve, sodbuster, swampbuster, and cross-compliance) that can produce indirect agricultural water pollution control benefits, but do not directly address water quality.

Agricultural water pollution and its control have not until recently been specifically or effectively addressed in other major federal pollution abatement laws, including the SWDA, Resource Conservation and Recovery Act (RCRA), and the Comprehensive Emergency Response, Compensation and Liability Act (CERCLA) (EPA, 1987a). The Wellhead Protection Program in SWDA can specifically address potential agricultural contaminants, while the Sole Source Aquifer (SSA) Program, established by Sec. 1424(e) of the SWDA, can include agricultural contaminants. In addition, the Underground Injection Control Program of the SWDA deals with farmland drainage injection into aquifers.

Regulatory Authorization and Implementation Mechanisms

NPS and groundwater pollution abatement programs are administered through the states. The 1972 CWA NPS amendment provided planning funds through Section 208. These terminated in 1981 and were followed by the Rural Clean Water Program (RCWP) which provided demonstration/research funding for 21 projects (later reduced to 20) across the nation. Section 319 of the 1987 CWA authorized planning and limited implementation funds to states for assessment of NPS problems and development and implementation of programs for their control. Each state program is required to identify "... best management practices and measures which will be used to reduce pollutant loadings resulting from each category, subcategory, or particular nonpoint source..., taking into account the impact of the practice on groundwater quality". Note that groundwater protection is not a specific criterion of BMPs, but the impact of the BMP on groundwater must be considered.

Classification and Categorization of BMPs

The concept of BMPs was developed specifically to deal with agricultural NPS pollution problems. The concept incorporates the voluntary approach used by agricultural agencies in addressing such problems as water and wind erosion. Also, it was early recognized that monitoring adoption of BMPs by farmers was far easier than monitoring edge-of-field changes in NPS pollution as a measure of compliance. BMPs include those practices previously promoted by conservation and extension agencies for maintenance of soil productivity and for increased production, but in recent years have been expanded to deal specifically with NPS pollution. Some BMPs, such as conservation tillage or tile drainage, are attractive because they meet many pollution control objectives and provide economic benefits to the farmer as well. Agricultural BMPs can be categorized according to the environmental objective to be met, the target pollutant, the environmental media affected, and the management approach of the specific practice. In this regard, the word "practice" is misleading in that many BMPs are structural measures.

Environmental Objectives: Table 1 summarizes BMPs for specific environmental objectives including control of erosion, eutrophication, salinity, water quality improvement, and proper waste management. It is clear that those practices which control pollutant loads (source control) will be effective for both surface and groundwater control, whereas practices which involve hydrologic modification, e.g., increasing infiltration to reduce surface runoff, may involve tradeoffs between surface water quality protection and that of groundwater.

Pollutant Type: Table 2 summarizes BMPs by pollutant type. It is important to note that those pollutants that are primarily associated with soil and sediment, such as phosphorus, organic nitrogen, heavy metals, some pesticides and BOD, can be controlled in surface water to greater or lesser degrees with the same BMPs used for erosion control. The greater the association with soil or sediment, the more effective is the soil erosion BMP. Conversely, those pollutants, such as nitrate, some pesticides and salts, that are not bound tightly to soil and sediment are more susceptible to leaching to groundwater. For these mobile pollutants, source control or treatment (either natural or controlled) will be required. The classification given in Table 2 for pollutant types could be further grouped on the basis of their association with sediment, using the partition coefficient (K_d) or the organic matter-normalized K_{oc} (see Rao et al. (1983) for definitions of K_d and K_{ow}; Baker and Johnson (1983) use the partitioning of chemicals between sediment and water to evaluate the effectiveness of agricultural BMPs for control of pollutants in runoff and tile drainage.)

Media Affected: Table 3 summarizes BMPs by general category in terms of the media affected by the pollutant. Here we are looking at tradeoffs between protecting surface water versus groundwater, or atmospheric contamination versus groundwater. Managing the soil to promote post-growing-season denitrification of nitrate will reduce nitrate leaching to groundwater but will increase nitrous oxide emissions to the atmosphere. Increasing water infiltration by terracing or no-till will reduce pesticide runoff at the expense of increased potential for movement to groundwater.

Management Approach: There are three general approaches to the control of agricultural NPS pollutants. Structural controls, such as terraces, grassed waterways, buffer strips, tile drains, irrigation systems, livestock waste storage facilities and sediment detention basins, are primarily designed to modify pollutant transport in water by reducing water use, rerouting water, or retaining water. They are particularly effective for control of sediment and sediment-associated pollutants in surface runoff, but several may offer benefits for groundwater protection as well. Tile drainage, for example, can reduce the potential for groundwater contamination by intercepting percolating water and returning it to the surface drainage system. Drip irrigation systems reduce water use and the potential for excessive leaching. Structural practices are relatively easy to regulate (precise design criteria can be developed) and install. They have a high capital cost and farmer implementation has generally required cost-sharing incentives. They require long-term maintenance and are often seen as a substitute for changing management. There are few direct incentives for short-term tenants to install structural practices.

Source controls are the most effective and easiest practices to regulate. They are, however, less acceptable to farmers than modifying management. As applied under FIFRA, specific pesticides can be restricted to specific crops or banned entirely. Criteria for labeling pesticides have been expanded to consider leaching potential. This together with specific site criteria (soil permeability, climate) could be used to restrict pesticide use in areas vulnerable to groundwater contamination. EPA's proposed pesticide strategy (EPA, 1987c) would have states develop "Pesticide Management Plans" to support the continued registered use of a particular pesticide in portions or all of the states. EPA is currently completing development of the strategy.

Nutrient application rates can also be restricted based on potential for surface or groundwater contamination. Nutrient loading restrictions are presently imposed for nitrogen applied to land as sewage sludge (federal law also limits the application of heavy metals, specifically cadmium, to agricultural land in sewage sludge), and several states restrict application of livestock waste

relative to nitrogen loading. The latter is not strictly enforced and there are no restrictions on chemical fertilizer application rates. Problems with imposition of nitrogen application limits include unpredictable nitrogen transformations in soil, leaching losses which could reduce crop yields, and difficulty in administering and regulating nitrogen use restrictions. More precise and timely nitrogen soil tests would strengthen the case for applying a nitrogen application limit.

Land Management practices manipulate the soil system to minimize the loss of pollutants in surface or ground water. Practices include timing and placement of chemicals to achieve maximum effect and minimum carryover; application methods for livestock waste to reduce runoff; irrigation scheduling to minimize water use and excessive leaching (irrigation scheduling may also reduce runoff if infiltration capacity is not exceeded); conservation tillage for runoff and erosion control. These practices do not offer the certainty of either structural or source control. Specific criteria for management practices are difficult to develop and significant education efforts over an extended period are required to attain large-scale impact. Those practices that are relatively easy to integrate into existing farming practices or offer an economic or labor-saving benefit are likely to be more readily adopted. Monitoring of adoption rates are difficult on a large scale. There is little evidence from the RCWP projects that significant implementation of management BMPs has been achieved at a watershed scale and less evidence for significant reductions in NPS pollution (Spooner et al., 1988). The latter is likely due to the lag time for NPS reductions caused by the inherent buffering of the system against change and the seasonal variation in climate that can mask real trends in pollutant loadings. Evaluation of the RCWP projects suggested that one area in which reductions can and were achieved is nutrient losses from livestock operations. This is likely because of the high concentrations of nutrients associated with manure disposal compared to normal fertilizer application practices. Livestock waste BMPs are a combination of structural (manure and wash water storage) and management practices (rate, method and timing of manure land application). Both offer promise for reduction of nitrate movement to groundwater.

Pest Management practices, primarily integrated pest management (IPM), that are designed to reduce the use of pesticides, offer the potential for reducing pesticide groundwater contamination. Although IPM is often described as a BMP, it is actually a concept that is much broader than a practice or practices. Because it involves such a major departure from the prevailing approach to pest management, it has not been readily adopted by many farmers despite extensive educational programs in the 1970s and 1980s.

Categorization of BMPs for Groundwater Protection: BMPs for groundwater protection must consider: those conditions that permit significant movement of infiltrating water to groundwater, the solubility and soil affinity of the specific pollutant, pollutant loadings, and the ability of the specific BMP to alter any of these conditions. A useful categorization of groundwater BMPs would include the following:

Soil Type - identification of soil profile characteristics that control water movement, including slope, texture, structure, infiltration capacity, hydraulic conductivity, and depth to water table.

Climatic Variables - rainfall distribution, evapotranspiration, temperature

Pollutant Characteristics - water solubility, water/soil partition coefficient, and soil residence time (includes degradation, immobilization, volatilization, photodecomposition). These are normally used to screen pesticides (see Table 4), but the same principle can be applied to any pollutant.

BMP Impact on Water Movement - practices which reduce infiltration, increase evapotranspiration, retain water in the root zone, intercept percolate and reduce water use would be candidates for groundwater BMPs. Tradeoffs with surface water contamination will have to be considered (no-till reduces runoff and erosion but increases infiltration, Logan et al., 1987; tile drainage intercepts percolating water below the root zone and returns it to the surface, Baker and Johnson, 1983), as will tradeoffs with crop production.

BMP Impact on Pollutant Characteristics - practices include changes in formulation of pesticides and fertilizer; methods of application of pesticides, fertilizer and manure; practices which enhance degradation, volatilization, adsorption, and chemical precipitation (here again, tradeoffs with pollution of other media, and crop production must be considered).

BMP Impact on Pollutant Loadings - indirect practices, such as IPM, irrigation management, using manure nutrient credits, and more efficient fertilizer use, are likely to be adopted without regulatory intervention if they are perceived by the farmer to increase productivity and economic returns. Management requirements for these practices are high and will require intense educational efforts over a generation of farmers to become entrenched as acceptable farming practices. These practices have been promoted by agricultural extension for two decades with minimal effect. Economic pressures and disincentives produced by federal support programs have been major impediments to widespread adoption, as well as the bias in most extension programs toward production versus environmental protection.

Regional Differences in BMPs and BMP Adoption

There are few national surveys of BMP usage with the exception of the Conservation Technology Information Center (CTIC) annual survey of conservation tillage use (Mannering et al., 1987). BMPs vary with crop distribution, livestock enterprises, and climate and soil characteristics. By far the most extensive set of BMPs are those promoted by SCS and state conservation agencies for erosion control. Of these, adoption of some form of conservation tillage has been the most extensive. Livestock waste management practices have been most heavily promoted in those states with the highest concentrations of livestock but most of the practices deal with manure storage and there is little effect on manure nutrient loadings to land. Of these two broad categories of BMPs, erosion control practices usually have little effect on groundwater protection and may in some situations increase leaching of pesticides and nitrate to groundwater (see Logan et al., 1987 for an extensive discussion of conservation tillage on groundwater contamination by pesticides and nitrate). Livestock waste management

practices that primarily focus on manure storage and do not deal with the problem of excessive application rates will have little or no impact on nitrate movement to groundwater, and may even increase nitrate leaching potential by concentrating the period when stored manure is land-applied.

Effectiveness of BMPs

The effectiveness of BMPs can be rated in terms of their impact on pollutant loads (e.g., kg/ha/yr of phosphorus in surface runoff), acceptability by farmers, cost-effectiveness, and ease of implementation and maintenance. An effective BMP is also one that has minimum negative impact or tradeoffs. Clearly, source controls for the most part meet all of these criteria, and for intractable pollutants, such as the pesticide EDB, total ban is the only solution. This approach can be applied only where there are suitable alternatives, such as substitute compounds. Source reductions are also effective if the degree of reduction is large enough to have an impact on pollutant loadings. Reducing manure applications to land from 20-30 tons/acre/year down to 5-10 tons/acre/year will have a significant impact on nitrate leaching. Reducing nitrogen fertilizer use by 10 percent will have much less effect. Source control is also most effective where the potential for transport to surface or groundwater is high. Back siphoning in chemigation systems, discharge of pesticide rinse water directly to streams or in the vicinity of wells, and direct runoff of manure produce very high local concentrations of pollutants which should be under source control.

BMPs which reduce the transport of pollutants to surface or groundwater are less effective than source controls. Their impact is dictated by variability in local climatic and hydrologic conditions, which are difficult to account for, making it difficult to reduce leaching of groundwater contaminants. In irrigated agriculture, however, there are more opportunities to decrease subsurface drainage, although leaching for salt control may be required.

POLICY ISSUES AND CONFLICTS RELATED TO GROUNDWATER PROTECTION

Factors affecting BMP Implementation

Farm Level: With the exception of conservation tillage (but not no-till), BMPs have generally been poorly adopted by farmers except in special projects, such as the Model Implementation Projects (MIP) or the RCWPs where high levels of cost sharing and technical assistance were available. Even here, the practices most widely adopted were not necessarily those producing the greatest water quality benefit (Spooner et al., 1988). This is a result of the inability or unwillingness of implementation agencies to effectively direct BMPs for maximum impact. Agencies have been unable to concentrate resources on a few farms and are more likely to widen the criteria for site selection to make cost sharing available to most farmers willing to participate. This diffusion of effort results in lower effective control of pollutants and makes it difficult to monitor effects even when they are likely to occur. The NWQEP evaluation of the RCWP projects (Spooner et al., 1988) suggests that the most effective BMPs are those that the farmer is likely to maintain after cost sharing is terminated. This is an essential consideration since NPS pollutant levels in a watershed are strongly buffered by natural watershed processes. Pollutant-contaminated sediments build up in ditches, rivers, estuaries and lakes and must be flushed out, buried or dredged before changes in water quality can be observed. This author believes that for sediment-associated pollutants, such as phosphorus or DDT, the response time is on the order of a decade after significant implementation of BMPs. This suggests that BMPs must be maintained in this time frame and longer. The 10-year contracts associated with the conservation reserve component of the 1985 Food Security Act begin to meet the needs for BMP implementation.

Directing BMPs and funding for their implementation (cost sharing, technical assistance, education) have been identified in most agricultural NPS pollution abatement projects as essential for maximum impact (Spooner et al., 1988; Morrison, 1977; EPA, 1987d). This recognizes the reality that sufficient resources will never likely be available to treat all sources of pollution. Efficient allocation of surface and groundwater protection funds is made more

difficult by a lack of water quality criteria in selecting areas for treatment. SCS and state conservation agencies have relied heavily on soil erosion rates and the concept of soil loss tolerance (Hall et al., 1985) to target many land treatment practices. These, however, may not be correlated with the particular water quality problem. Watershed computer simulation models, such as ANSWERS (Beasley and Huggins, 1980), offer an effective means of identifying critical areas of surface water NPS pollution. Groundwater models (van der Heijde and Beljin, 1988) provide similar capabilities for identifying critical areas for groundwater protection. Once identified, these areas can be selected for intensive, long-term treatment. Because of their limited area, impacts of BMP adoption can be more easily monitored. Recent developments in geographical information systems (GIS), computer modeling and remote sensing technology suggest that the limiting factor in effective application of BMPs to critical areas is political will and inadequate funding for implementation.

Institutional Level: There are a number of institutional issues that affect the implementation of a groundwater protection program based on agricultural BMPs. In the first place, most existing agricultural NPS programs are administered by the states. An exception to this is in Nebraska where local Natural Resources Districts have the authority to administer NPS programs (Central Platte NRD, 1985). The federal government has provided planning funds through the CWA but only limited implementation funds have been appropriated other than the MIP, RCWP, Clean Lakes, Great Lakes and other specific demonstration projects. Specifically, the CWA provides implementation funds for the Chesapeake Bay program under Sec. 117, and Sec. 201(g)(1)(B) of the CWA (referred to as the Governor's Discretionary Fund) provides modest funds to individual states.

The state NPS plans and the demonstration projects have had little or no groundwater protection focus. A few states, notably Wisconsin and Iowa, have developed agricultural NPS abatement programs and have provided some implementation funding, but the focus is on erosion control and livestock waste management. California has a strong groundwater

protection program that appears to be adequately funded (Wilkerson and Kim, 1986), and the passage of Proposition 65 in California will likely result in even greater groundwater protection activities in that state.

Secondly, there have been until recently no specific groundwater protection programs in USDA extension, research or conservation agencies. Groundwater policies have been developed in the last year that commit Cooperative Extension (CES), Agricultural Research Service (ARS), Soil Conservation Service (SCS), Geological Survey (USGS) and Cooperative State Research Service (CSRS) to nationwide programs in groundwater protection (USDA, 1987). These involve actual commitment of resources to groundwater, but given the declining real dollar budgets of these agencies in recent years, the impact of these efforts will be minimal. The greatest impact of these policies and the memoranda of understanding recently signed by EPA and the agricultural agencies will be the opportunity to coordinate activities in groundwater protection at state and local levels and to develop BMPs that are consistent across the agencies operating at the field level.

Methods of Accurately Assessing BMP Implementation

There are basically two approaches to assessing BMP implementation and its impact on water quality. In the first approach, simulation modeling is used to determine the BMPs to be used, the extent of implementation of the various practices required, and where practices should be implemented in order to achieve a given pollution abatement objective. This objective is often given as a reduction in sediment or nutrient loading from a watershed, attainment of an ambient water quality standard, such as dissolved oxygen, or reduction in concentration of a given pesticide. This is essentially a risk assessment and risk management approach, although modern risk assessment methods have not been systematically incorporated into model simulations. Once BMP implementation goals and plans have been developed, implementation has been monitored on the basis of extent of installation of the individual practices. This can be done by monitoring disbursement of cost sharing funds and development of conservation plans

by soil and water conservation districts, by surveys of farmers and district technicians (this approach has been used by CTIC in their annual surveys of conservation tillage), and by remote sensing. In the latter approach, aerial photography and satellite imagery are used to identify practices such as conservation tillage. This approach is still in a development stage, but offers advantages of greater assessment objectivity and more precise identification of locations where practices have been applied.

The second approach to assessing BMP implementation is to monitor water quality change. This is ultimately necessary in order to validate the simulation modeling on which the pollution abatement plan was based, and to evaluate the effectiveness of BMPs in achieving desired water quality goals. This approach also incorporates positive and negative effects of non-project activities in the watershed. Monitoring water quality change is a long-term proposition and will have to consider normal year-to-year variations in watershed processes in order to quantify accurately real change. Long-term baseline monitoring of surface and ground water is an essential component of this approach.

Strengths and Weaknesses of BMP Approach in General

The BMP approach was developed by the environmental and agricultural agencies as a means of addressing NPS problems in a manner that was compatible with the traditional, voluntary approach to resource management. It was widely believed by the agricultural community that the bottom-up approach used for erosion control could be applied to the problems of NPS pollution. This approach has failed to produce significant national reductions in NPS pollution. It can be argued that NPS pollution abatement programs were never funded beyond the planning and demonstration stages, and that it was naive to expect states to implement programs that had little grassroots support. Environmental pollution has not been a major issue with the agricultural community but has rather been championed by environmental groups with a generally urban base. It is, therefore, not surprising that BMPs have not been widely accepted by the agricultural community in the absence of cost sharing or a clear economic advantage for

the practice. The experiences of the MIP and RCWP projects suggest that full funding of NPS pollution abatement programs, using the voluntary BMP approach, will not necessarily produce the desired pollutant reductions. Resources must be directed to problem areas with BMPs that will have the greatest long-term impact. Farmers must be motivated through education, technical assistance, cost sharing where necessary, and some regulatory sanctions to deal with agricultural pollution problems. Farmers' concerns for groundwater protection will be greater than for surface water because farm families are increasingly worried about contamination of their own wells. The groundwater pollution problem is not off-site, someone else's problem, but one affecting the farm family directly. This concern needs to be considered in developing education programs for pollution control.

Voluntary adoption of BMPs as a means of addressing agricultural NPS pollution problems has a number of benefits that should be carefully considered before proposing alternative methods. It is obviously more acceptable to farmers, it offers more flexibility for site-specific conditions and farmers' abilities to adopt BMPs, and it does not require the level of enforcement required of a strictly regulatory approach. The farming community has argued that the voluntary approach is more appropriate than regulations because, unlike industry which can directly pass on costs of production to consumers, farmers have no mechanism to internalize regional differential costs of pollution abatement. Application of a regulatory approach to NPS pollution problems has the significant problem of identifying measurable and enforceable water quality standards and the resources that would be needed to monitor compliance on the millions of acres of agricultural land (the area involved would be large even with differential regulations for critical and noncritical areas). Despite the appeal of the BMP approach to NPS agricultural pollution abatement, the lack of significant adoption of these practices in the 15 years since they were proposed suggests that other measures must be considered if water quality benefits are to be realized.

Strengths and Weaknesses of BMPs for Groundwater Protection

Characteristics of Groundwater Protection BMPs: As previously discussed for BMPs in general, groundwater BMPs can either control the source of the pollutant, the movement of water (in this case percolating water) carrying the pollutant, or it can aid in transformation of the pollutant to a non-polluting form. Of these three strategies, source control is the most effective and easiest to regulate. Water management can be effective in irrigated areas, but more difficult in areas of high rainfall. BMPs which involve pollutant transformation, such as use of a nitrification inhibitor to slow down the formation of nitrate from ammonia, are subject to considerable local variability and produce marginal benefits.

Effectiveness of Specific Practices: Table 5 summarizes groundwater BMPs for nitrate and pesticides by general category. The degree of effectiveness rating given is the intrinsic effectiveness of the practice. The overall effectiveness of a practice will be determined by the degree to which it is implemented. For nitrate, the most effective approach is restricting application rate to coincide with crop requirements. This is particularly true for corn, potatoes and other crops which have high nitrogen fertilizer requirements, for land application of livestock wastes, and irrigation water management (Branson et al., 1975). Extensive research on nitrogen movement in tile drainage (Baker and Johnson, 1983) and to deeper groundwater confirm that restricting nitrogen application rates to those required for near optimum yields is in most cases an effective control on nitrate concentrations in excess of the drinking water standard of 10 mg/liter NO_3-N. The difficulty is in establishing nitrate rate limits that protect the farmer against seasonal variation in nitrogen use efficiency by the crop, and non-leaching losses, such as denitrification. More nitrogen-use efficient practices, such as split applications, have not been widely accepted by farmers because of the greater time and management required as well as the risks of crop yield reductions with these practices. Nitrogen use by crops is more predictable in irrigated areas where soil moisture conditions are more controllable.

Applying a strict nitrogen application rate limit to lands receiving livestock waste would have a significant impact on nitrate levels in local groundwater in areas where concentrated livestock

operations result in excessive manure applications. This approach is presently successfully used with land application of municipal sewage sludge (e.g., Ohio EPA, 1983) and is used by a number of states for manure spreading (for Ohio, Mr. Matt Tin, Ohio EPA, personal communication). While monitoring of day-to-day manure application is not feasible, manure management plans for the entire livestock operation can be required to establish if the land base is adequate for application at nitrogen crop utilization rates.

Pesticide contamination of groundwater is very compound- and site-specific. This specificity suggests that the problem is not as widespread as that of nitrate contamination and also offers insights for its control. FIFRA provisions now include leachability of the compound, and could be expanded to include label restrictions based on site- or region-specific soil, bedrock and climatic conditions favoring pesticide movement to groundwater. This is essentially the approach employed by California (Wilkerson and Kim, 1986). The recent Wellhead Protection Program (EPA, 1987b), which establishes statutory requirements for state wellhead protection programs, is an effective approach to protecting public water supply wells and could be expanded over time to include private wells. Applicator training under FIFRA and extension education programs will be needed to implement wellhead protection measures, but these are measures that are likely to be accepted by farmers. Good housekeeping measures, such as better rinsing and disposal of pesticide containers, and sprayer calibration, are likely to be very effective in protecting individual wells.

IPM has the potential to greatly decrease pesticide use and, therefore, the risk of groundwater contamination. IPM comprises a broad set of practices, and it is, therefore, difficult to quantify IPM adoption. It appears, however, that the full range of IPM practices has had only limited acceptance by farmers (Virginia CES, 1987). IPM requires considerable time and greater management skills and may be perceived as riskier than prophylactic or calendar-scheduled pesticide use (Cochran and Bogess, 1988). Unless mandated by law, or unless extension and research priorities shift more dramatically in favor of IPM, it is unlikely to have much impact

on future pesticide use. It should be noted that federal funding for IPM education programs have decreased over the last decade, and there has never been more than token federal funding for other pesticide education programs.

Compatibility With Other Agricultural Management Practices: As previously discussed, there are many tradeoffs between surface and groundwater protection strategies and practices. The most widely discussed of these has been the use of conservation tillage, and particularly no-till, for sediment, phosphorus and runoff control (Logan et al., 1987). This practice has been promoted by USDA and EPA as a BMP for NPS pollution control and has been adopted extensively and enthusiastically by farmers because of the production benefits of this practice. Concern has been voiced, however, that this practice requires greater use of pesticides than plowing (Maas et al., 1984) , and that increased water infiltration increases the potential for pesticides and nitrate to move to groundwater (Baker, 1987). A panel of experts (Logan et al., 1987) considered this issue in detail and concluded that the risk of groundwater contamination from extensive adoption of conservation tillage was minimal for several reasons. Fawcett (1987) found that the actual use of pesticides by "conventional" (i.e. moldboard plow) farmers and those practicing conservation tillage was similar, especially after several years when farmers had developed more confidence with conservation tillage. They also found that most farmers were practicing conservation tillage in limited forms, such as using a chisel plow rather than complete inversion tillage. They concluded that the differences in water infiltration and percolation between plow-based systems and these intermediate systems were small and would have limited effects on chemical movement to groundwater. They also concluded that the benefits of conservation tillage far outweighed the potential negative impacts.

Research Requirements for Groundwater BMP Development: Groundwater and its contamination have been researched far less than surface water. Impacts of agricultural practices are primarily confined to the surface soil, root and vadose zones. Chemical movement

is often by unsaturated flow, and there is recent evidence for preferential flow in biochannels and soil cracks (Edwards et al., 1988). There have been only a handful of field studies on effects of agricultural practices on groundwater contamination. Much of the cause-and-effect evidence is based on field surveys of groundwater in agricultural areas (Hallberg, 1985). Interpretation of BMP impacts on groundwater protection have been taken from studies of tile drainage, shallow wells, or irrigation return flow.

Major research needs for groundwater BMP development include: a) development of better unsaturated flow chemical transport models; b) development of more precise nitrogen soil and plant tissue tests; c) improved chemical application technology; d) development of better IPM methods and other non-pesticide options for pest control; e) development of a national GIS to include land use, soils, topography, geology and hydrology, together with better groundwater pollution screening models; f) direct field-scale evaluation of BMPs on nitrate and pesticide movement to groundwater.

ALTERNATIVE METHODS OF GROUNDWATER PROTECTION FROM AGRICHEMICALS

Specific Examples of Alternative Methods

Conservation Plans: The 1985 Food Security Act requires farmers receiving support payments to have a fully implemented conservation plan in place by 1995. There will be little groundwater protection from this program for many reasons. First, there are no water quality provisions in the cross-compliance measure, and certainly none for groundwater protection. The emphasis is primarily on erosion control, and the majority of BMPs that will be adopted are conservation tillage, terraces, grass waterways and other traditional erosion control measures. As previously discussed, these provide some surface water quality benefits for sediment, phosphorus and sediment-bound pesticides, but have no impact on groundwater quality (although some argue that these practices may increase chemical movement to

groundwater). Second, the resources of SCS and state agencies will be stretched thin in trying to meet the deadlines mandated in the Act. Third, SCS has recently changed the erosion control objectives of the Act (they were designed to meet as near as possible the soil loss tolerance value, T, which ranges from 1-5 tons/acre/year) to the point where they are in some instances more lenient than existing state erosion control guidelines (Mr. Jerry Wager, Ohio Department of Natural Resources, personal communication). Fourth, development of a conservation plan does not guarantee that it will be implemented and there are insufficient federal and state resources to monitor compliance. Fifth, there is little or no directing of resources in the cross-compliance section of the Act, and so any benefits in sensitive groundwater contamination areas will be much less than if efforts were differentially allocated.

SCS has used farm-level conservation planning for decades in helping farmers deal with their erosion problems. The approach has been strictly voluntary, the agency has taken the generally passive role of responding when requested, and the goal has been maintenance of on-farm soil productivity. Off-site water quality has not been a primary issue to date. SCS has recently begun to update its technical guides and to train state technicians to incorporate water quality goals into conservation planning (Dr. David Schertz, National Agronomist, USDA-SCS, Washington, DC, personal communication). The intent is to ensure that conservation planning is consistent with general water quality goals but specific practices for nutrient or pesticide management are not required. This is an important step by SCS, however, as it is the primary field-level technical assistance agency in most states.

Nutrient Management Plans: These have been developed primarily for NPS phosphorus control (Forster et al., 1985) but have never been implemented sufficiently to achieve meaningful results. The Army Corps of Engineers (COE, 1982) developed a plan for reduction of total phosphorus loads to Lake Erie to achieve a 90 percent reduction in anoxic conditions in the central basin caused by eutrophication. The plan proposed extensive voluntary adoption of conservation tillage, livestock waste management and phosphorus fertility management to

achieve the desired reductions. Implementation was to be achieved by expanded technical assistance and education with limited cost sharing for manure storage. The proposal was not funded.

Nitrogen management has been encouraged for livestock waste disposal and is mandated for livestock operations with more than 1000 animal units under NPDS regulations. The emphasis has been on manure storage to reduce direct runoff to streams and lakes. The problem has been, however, that in many areas the operator does not own or have access to sufficient land to apply the stored manure at rates to avoid nitrate leaching. Storing manure for seasonal application can exacerbate the problem by concentrating nutrients in time and space. Another problem with nitrogen management in livestock waste disposal is that farmers often do not fully credit the nitrogen supplied by the manure in making fertilizer application decisions. Nitrogen fertilizer is often applied when manure nitrogen is more than adequate for the crop. Manure analysis and educational efforts have had little impact on reversing the perception of many farmers that supplemental fertilizer is needed.

Presently, most nitrogen management plans do not differentiate between soils with varying potential for nitrate leaching. Directing management efforts to sensitive areas would reduce the area on the farm requiring stringent nitrogen rate restrictions.

Pesticide Management Plans: Pesticides are presently regulated through FIFRA and state programs such as that in California (Wilkerson and Kim, 1986). Regulation is achieved through pesticide screening, label restrictions and applicator certification. Of these, the first is the most effective and can be modified to better consider pesticide leachability. Once the pesticide is labeled, management is in the hands of the applicator. Management options at this point would be to require that pesticides be applied by certified applicators, particularly in sensitive groundwater areas, although there is no guarantee that certified applicators will be more conscientious than individual farmers. Monitoring an increasing number of certified applicators will stretch state agency resources even further. On-farm pesticide management should stress

good housekeeping measures (such as proper cleaning of sprayers, disposal of spray rinsate, and disposal of pesticide containers); selection, maintenance and calibration of appropriate application equipment; and adherence to wellhead protection provisions. This can be most effectively addressed by aggressive extension education programs in concert with statewide farm well testing. Farm families will likely respond to evidence that their wells are contaminated.

Whole-Farm Environmental Assessments: An important question to be asked concerning agricultural pollution abatement is do we focus on the farm or the farmer for regulation or management? Is the farm or the farmer the problem? In the days of the predominantly family farm, the two could be treated as one. An environmental assessment would consider the physical constraints contributing to the pollution problem as well as management deficiencies. Today, however, farmers are managing their own property as well as rented or leased land. Often, the family farm is smaller than the rented or leased land. Groundwater contamination is clearly a site-specific problem and regulation or management must be directed to the site. These measures would have to be followed by the farmer, be it owner or tenant, but the question of responsibility would have to be decided.

Whole-farm environmental assessments are technically feasible today. Conservation planning currently practiced by SCS and the local conservation districts could be expanded to address surface and groundwater problems. What is lacking is the regulatory authority or the technical assistance resources. Since resources are always likely to be limited, and regulations should only be applied where the environmental problem is severe enough to warrant them, whole-farm environmental assessments should be directed to sensitive areas.

Low Input/Sustainable Agriculture Systems: As a result of agricultural environmental problems and downturns in the U.S. farm economy, there has been a growing questioning of the entire U.S. agricultural production system. U.S. agriculture is perceived by some as too production oriented, in a time of excess production, and nonresponsive to environmental

problems. There is a feeling that agriculture must become more harmonious with the natural system if it is to be "sustainable." This question of sustainability has sparked lively debate (Odum, 1987) and is interpreted differently by various groups. Organic farmers and others argue for "low-input" farming systems that minimize the use of synthetic fertilizers and pesticides but rely rather on biological nitrogen fixation and animal waste for fertilizer, and cultural and biological pest control. Another term for this type of farming is "regenerative" agriculture which also encompasses the concept of improving the "health" of the soil. An important tenet of these systems is that absolute production should not be the primary goal but rather a system that results in minimal environmental disturbance. In terms of groundwater protection, substitution of biological and cultural pest control for pesticides would obviously eliminate pesticide groundwater contamination. These systems will not necessarily reduce nitrate contamination of groundwater, however, unless nitrogen is managed properly. The problems of excessive manure application will still exist even though the farmer may use no chemical fertilizer. A green manure crop plowed under at the wrong time can release large amounts of mineral nitrogen which could leach below the root zone before the succeeding crop can utilize it, although there are no reported studies to determine how important this might be (Logan and Hallberg, 1989).

The debate over sustainable agriculture is healthy as it forces agriculture to question its basic premises. It is unlikely, however, that there will be more than a modest movement in this direction by U.S. farmers in the next decade. The shift to low-input methods requires a dramatic change in management, is often accompanied by drastically lower initial crop yields, and requires much greater labor input. Unless forced by environmental regulation or other inducements, few present-day farmers will perceive enough benefits from low-input systems to warrant the drastic changes involved. In addition, the 1988 drought questions whether agricultural surpluses in the U.S. are likely to continue, and another drought year, coupled with the effects of the conservation reserve program, could result in pressures for greater production (Brown et al., 1989).

Regional/Watershed Management Plans: As indicated previously, watershed management plans have been developed to handle regional water quality problems, such as Great Lakes (COE, 1982; Forster et al., 1985) and Chesapeake Bay (Chesapeake Bay Executive Council, 1985) eutrophication. They have, with the exception of Chesapeake Bay, however, never been implemented. Modest attempts at implementing watershed water quality management plans were made in the MIP and RCWP projects, the Black Creek project in Indiana (Morrison, 1977) and Honey Creek in Ohio (COE, 1982). These were all developed to address surface water quality problems, and have met with only limited success. The Big Springs study in Iowa (Hallberg, 1985) has addressed the problems of nitrate and pesticide contamination of groundwater. This watershed occurs in an area of karst bedrock geology which permits rapid movement of surface water to groundwater through large cracks and weathering channels. BMP implementation has been minimal to date and results are inconclusive. Several Natural Resources Districts in Nebraska have begun to implement NPS groundwater quality management plans (Central Platte NRD, 1985). These allocate groundwater for irrigation, and require metering of irrigation wells and irrigation scheduling, among other provisions.

The primary failure of the watershed projects is the lack of selective resource allocation, the short duration of the projects and the low priority of water quality versus erosion control in selection of BMPs for funding.

Other Approaches: A number of mechanisms could be used to address critical groundwater contamination problems. The key would be to identify specific areas vulnerable to contamination and where groundwater use warrants its protection. Regulations and resources would be directed to these areas. A screening process could be used to select protection measures, with the number of candidate measures declining as the intractability of the problem increased. Ultimately, the problem may be so intractable that only two options exist: take the land permanently out of production (a permanent conservation reserve) or, in the case of a particular pesticide, ban use of the pesticide in that area. The latter is used in California

(Wilkerson and Kim, 1986). A provision of EPA's proposed pesticide strategy (EPA, 1987c) is to cancel or change the registered use of certain pesticides in particular areas unless a "Pesticide Management Plan" is developed by the state. Another alternative which could be considered for localized, intractable groundwater contamination is point-of-use treatment. This approach might be the most cost effective for private wells and could be borne by the polluter in the form of a regional tax on chemical use. Treatment might also be feasible for small community systems.

How Do Alternative Methods Address Policy Issues and Conflicts?

The major policy issues and conflicts surrounding agricultural groundwater contamination and measures for its remediation include: a) tradeoffs between surface and ground water protection; b) crop production and water quality; c) critical area approach versus uniform efforts; d) voluntary versus regulatory approaches; e) monitoring BMP adoption and success; f) groundwater treatment versus groundwater protection.

Trying to adapt the existing BMP approach to deal with groundwater problems has the advantage of minimal disruption of existing education and technical assistance delivery systems and preserves the voluntary approach favored by agriculture. The problem is that the voluntary BMP approach has not been successful at solving surface water quality problems or even those of excessive soil erosion. Insufficient resources and a lack of selective allocation appear to be major reasons for failure. The BMP approach will also produce tradeoffs between surface and groundwater quality, conservation tillage, terraces and tile drainage being a few examples. In most cases, existing BMPs should have little negative effect on production.

Of the various conservation features of the 1985 Food Security Act, only the conservation reserve and swampbuster provisions provide definite groundwater quality benefits as both essentially exclude agricultural production. The 10 year period could be extended for sensitive groundwater areas. The cross-compliance provision, which requires eligible farms to have

conservation plans in place by 1995, will have little or no groundwater benefit since groundwater quality is not an objective in the conservation plan and there is recent indication that the conservation requirements will be weak.

Nitrogen management plans will be difficult to mandate and to manage because of the high variability in the behavior of nitrogen in soil and the sensitivity of most crop yields to changes in nitrogen availability. To guarantee no significant nitrate leaching to groundwater, farmers will have to estimate nitrogen needs much more precisely and this will require better soil nitrogen tests than are now currently available. Yield goals and associated nitrogen application rates would have to be lowered somewhat to provide a margin of safety. This option should only be considered for highly sensitive groundwater areas. Even with the best package of nitrogen fertilizer BMPs, reductions in nitrate leaching might be minimal. In contrast, irrigation management in sensitive groundwater areas is likely to produce greater reductions. Likewise, improvements in livestock waste management have the potential for major reductions in local nitrate contamination because excess nitrogen application with livestock waste often far exceeds that of fertilizer. Production should not be affected in this case since the problem is one of large nutrient excesses.

Pesticide management will be most effective if it is applied at the point of pesticide development, registration and labeling, and the existing FIFRA regulations should be strengthened to more specifically address pesticide leachability. Implementation of EPA's proposed pesticide strategy will also provide a basis for states to address problems with specific pesticide compounds. Labeling should be site specific so that leachable compounds that are otherwise environmentally acceptable can be restricted to nonsensitive areas. Good housekeeping should be a major focus of extension education and, together with a state program of individual well testing, can build on growing farmer concerns for their own drinking water quality. These programs would have some production impact in sensitive groundwater areas where cheaper and more effective pesticides may be restricted.

Whole-farm environmental assessments should be a long-term goal for effective, integrated environmental management on the farm. Although technically feasible today, and often used informally by SCS in its conservation planning, costs of required whole-farm assessments would be very high and would have no impact on water quality per se unless there are regulatory provisions that will be imposed as a result of negative assessments. Because of the high costs of comprehensive environmental assessments, these should only be directed to the most environmentally sensitive areas.

Sustainable, low-input or regenerative agriculture is a relatively new concept in U.S. agriculture that has a strong, vocal, but small group of advocates and practicioners. The debate over this approach to agricultural production versus the current high-input system has been prominent in the last several years, and USDA in 1988 appropriated approximately $4 million for research and extension programs in sustainable agriculture. The benefits to groundwater protection of widespread adoption of this approach would be significant for pesticides but inconclusive for nitrate. There are no indications, however, that this relatively radical approach to farming will be adopted widely over the next decade.

Regional or watershed management plans have only been funded and implemented in a few instances (e.g., Chesapeake Bay and Nebraska NRDs). They primarily rely on existing BMPs and unless strictly targeted are unlikely to have major impact on surface or ground water quality. One feature of regional planning that has never been utilized for NPS pollution is the concept of pollution trading in which pollutant limits are determined for the region and pollutors can trade among themselves (Harrington et al., 1985). Theoretically, the pollutors with more cost-effective abatement technologies (practices) would take on a greater percentage of the pollutant load and be remunerated by pollutors with less cost-effective abatement methods. This would probably involve trading between point and nonpoint source polluters (the point source polluters theoretically having the more cost-effective control technology) and

between large and small pollutors. Trading currency, such as tax credits, would have to be developed.

Point-of-use treatment of groundwater from private and even small community wells needs serious consideration. The fraction of total water consumption for drinking and cooking is small compared to other household uses, and treatment of drinking water would likely be cost effective in selected areas where the problem is sufficiently intractable to make other remedial options difficult.

Conclusions

An examination of existing approaches to NPS water pollution abatement reveals several facts: a) NPS abatement programs have never been funded at a level that would allow sufficient implementation to evaluate their chances for success; b) the NPS demonstration projects indicate that even where significant resources can be brought to bear they are not sufficient to be effective; c) most existing BMPs are designed for erosion control and livestock waste storage and handling; few deal directly with either surface or ground water quality; d) measures which control the source of pollution are likely to be the most effective in terms of implementation and degree of control, and are preferable to adoption of BMPs which are usually only marginally successful at reducing NPS pollution; pesticide regulation under FIFRA is a good example of source control, as is the new Wellhead Protection Program; e) the most important local source of nitrate groundwater contamination is livestock waste disposal which should be directed for control; manure storage and handling BMPs will not solve the problems of disposal of excess manure nitrogen on limited crop and pasture land; f) programs for groundwater protection should not be separated from surface water protection programs, and vice-versa; g) long-term (years to decades) monitoring is needed to accurately determine BMP effectiveness at a realistic field scale.

Congressional Options for Groundwater Protection

1. Expand the provisions of FIFRA to screen new compounds more specifically for leachability. Beneficial impacts would be high and negative effects low or undetermined.

2. Develop a mechanism to restrict compounds from sensitive groundwater areas. This could be within FIFRA as a label restriction or as part of EPA's proposed pesticide strategy. Benefits would be high and negative effects low or undetermined.

3. Allocate extension and research funding for IPM and pesticide management practices, and develop incentives for farmers who adopt IPM practices. These might be in the form of indemnification of crop loss from unexpected occurrences during the transition from prophylactic pesticide use to IPM. Benefits would be high and adverse impact low.

4. Expand provisions of cross-compliance, sodbuster, swampbuster and conservation reserve to consider groundwater protection. Directing conservation reserve and swampbuster programs to sensitive groundwater areas in particular would have high benefit and minimal negative impact. Incorporating groundwater protection into cross-compliance will be difficult to achieve given the present weak conservation goals of the program and the number of farms involved. Some reorientation of this program could be considered, however.

5. Develop regulations for livestock waste disposal that will restrict nitrogen application rates in sensitive groundwater areas. The regulations would also have to address surface water nitrate contamination. Focussing on larger operations would be a possibility, but local problems are often associated with small, marginal operators. Cross-compliance for dairy support would be one enforcement mechanism but other livestock would have to be addressed as well. Local groundwater protection benefits would be high in sensitive areas but negative impact would be high, particularly for marginal operators.

6. Efficient irrigation management should be fostered in sensitive groundwater areas. Chemigation should be limited in these areas unless appropriate controls are used. Regulations

would probably be required unless some other mechanism, such as water allocation, is imposed. Local benefits would be high and long-term impact would be neutral.

7. Some mandatory controls on the most serious agricultural pollutants will have to be imposed if they are to be addressed in a reasonable period of time. In the case of pesticides, the regulatory approach is well established in FIFRA and would need little change to more effectively deal with groundwater contamination. The problem is more difficult for essential nutrients, which are naturally occurring, subject to considerable natural variation, and not readily amenable to control. This is particularly true for nitrogen. Nevertheless, some regulatory control may be required in areas most susceptible to nitrate leaching to groundwater.

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GLOSSARY OF ACRONYMS

ANSWERS	Areal Non-point Source Watershed Environment Response Simulation
ARS	Agricultural Research Service
BMP	Best Management Practice
BOD	Biological Oxygen Demand
CERCLA	Comprehensive Emergency Response, Compensation and Liability Act
CES	Cooperative Extension Service
COE	Corps of Engineers
CTIC	Conservation Technology Information Center
CWA	Clean Water Act
DDT	1,1,1-trichloro-2-(chlorophenyl)ethane
EDB	Ethylene dibromide
EPA	Environmental Protection Agency
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
GIS	Geographic Information System

IPM	Integrated Pest Management
MIP*	Model Implementation Program
NPDS	National Permit Discharge System
NPS	Non-Point Source
NWQEP	National Water Quality Evaluation Project
RCRA	Resource Conservation and Recovery Act
RCWP**	Rural Clean Water Program
SCS	Soil Conservation Service
SWDA	Safe Water Drinking Act
USDA	U.S. Department of Agriculture

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* The MIP was jointly funded by EPA and USDA to develop cause-and-effect data, test effectiveness of BMPs and assess farmers attitudes towards BMP implementation. Seven projects were funded between 1978 and 1982.

** The RCWP was established by the 1977 Amendments to the CWA. It was designed as a program of technical and financial assistance for implementation of BMPs in selected project areas. RCWP was administered by USDA and 20 projects were funded nationwide ($70 million over the period 1980-1982).

able 1. Classification of Agricultural BMPs by Environmental Objective

BMP	Primary Environmental Objective*
tructural	
errraces, hillside ditches	E
rass waterways	E
ubsurface (tile) drains, water table management	S
rrigation systems	S, E
hemigation backsiphon devices	Q
ediment and water retention basins	L, Q
urface drains	N, Q
anure storage, runoff control, filter strips	W, L, Q
rrigation tailwater recovery systems	E
ultural	
onservation tillage	E, L, Q
ontour cropping	E, L
trip cropping	E, L
ontour strip cropping	E, L
over cropping	E, L, Q
rop rotation	E
ubsoiling	S
and grading	S, E
ritical area planting	E, L, Q
tream bank protection	E
ow-input farming	E, L, Q
anagement	
ntegrated pest management	Q
nimal waste management	L, W, Q
ertilizer management	L, Q
esticide management	Q
rrigation management	S, L, Q

E = erosion control, L = eutrophication, W = animal waste management, = water quality, S = salinity, N = none (e.g., surface drains primarily liminate wettness problems).

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Table 2. Classification of Agricultural BMPs by Pollutant Type

BMP	Pollutant Type*
Structural	
Terraces, hillside ditches	E, P
Grass waterways	E, P
Subsurface (tile) drains, water table management	E, P, N, S
Irrigation systems	S, N
Chemigation backsiphon devices	C, N
Sediment and water retention basins	E, P, N
Surface drains	N
Manure storage, runoff control, filter strips	N, P, B, O, M
Irrigation tailwater recovery systems	E, C, S
Cultural	
Conservation tillage	E, P
Contour cropping	E,
Strip cropping	E,
Contour strip cropping	E,
Cover cropping	E,
Crop rotation	E
Subsoiling	S, E
Land grading	S, E
Critical area planting	E, P, N
Stream bank protection	E
Low-input farming	E, C
Management	
Integrated pest management	C, M
Animal waste management	N, P, M
Fertilizer management	N, P
Pesticide management	C, M
Irrigation management	S, N, P

*E = sediment, P = phosphorus, N = nitrogen, C = pesticide, B = BOD, S = salt, M = heavy metals, O = pathogenic organisms.

able 3. Classification of Agricultural BMPs by Media Impacted

BMP	Media Impacted*			
	Surface Water	Ground Water	Air	Soil
tructural				
erraces, hillside ditches	P	N/A	N	P
rass waterways	P	N	N	P
ubsurface (tile) drains, water table anagement	P/A	P	N	P
rrigation systems	P	P	P	P
hemigation backsiphon devices	N	P	N	N
ediment and water retention basins	P	A	A	N
urface drains	A	P	N	P
anure storage, runoff control, ilter strips	P	P	P	P
rrigation tailwater recovery systems	P	N	N	P
ultural				
onservation tillage	P	N/A	N/A	P
ontour cropping	P	N/A	N	P
trip cropping	P	N/A	N	P
ontour strip cropping	P	N/A	N	P
over cropping	P	P	N	P
rop rotation	P	N/P	N	P
ubsoiling	P	N/A	N	P
and grading	A	N/P	N/P	P
ritical area planting	P	P	P	P
tream bank protection	P	N/P	N/P	P
ow-input farming	P	N/P	P	P
anagement				
ntegrated pest management	P	P	P	P
nimal waste management	P	P	P	P
ertilizer management	P	P	P	P
esticide management	P	P	P	P
rrigation management	P	P	P	P

P = positive impact, A = adverse impact, N = no impact

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Table 4. Pesticide Characteristics Which Influence Leaching Potential

Pesticide Characteristic	Value or Range*
Water solubility	Greater than 30 ppm
Partition coefficient (K_d)	Less than 5, usually less than
Organic-carbon normalized partition coefficient (K_{oc})	Less than 300-500
Henry's Law constant	Less than 10^{-2} atm.m^{-3}mol
Speciation	Negatively charged, fully or partially at ambient pH
Hydrolysis half-life	Greater than 25 weeks
Photolysis half-life	Greater than 1 week
Field dissipation half-life	Greater than 3 weeks

* Parameter for indicating the potential for ground-water contamination

Source: EPA, 1986

Table 5. Agricultural BMPs for Groundwater Protection

BMP	Degree of Effectiveness*		
	Pesticides	Nitrates	Salt
Structural			
Irrigation systems	M	M	H
Chemigation backsiphon devices	H	H	N
Animal waste storage	N	M	L
Subsurface (tile) drainage	L	M	M
Point-of-use treatment	H	H	H
Cultural			
Critical area planting	H	H	N
Cover cropping	H	M	M
Low-input farming	H	L	N
Management			
Integrated pest management	M	N	N
Animal waste management	N	H	L
Fertilizer management	N	M	L
Pesticide management	H	N	N
Irrigation management	M	H	H
Focussing on sensitive groundwater areas	H	H	H

* H = high, M = medium, N = none

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